

Recent Progress in Analysis and Prediction at the NCEP Environmental Modeling Center

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Director*, EMC

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H-L Pan, S. Saha, M. Iredell

* Detailed to NWS/OST
until 30 June 2011



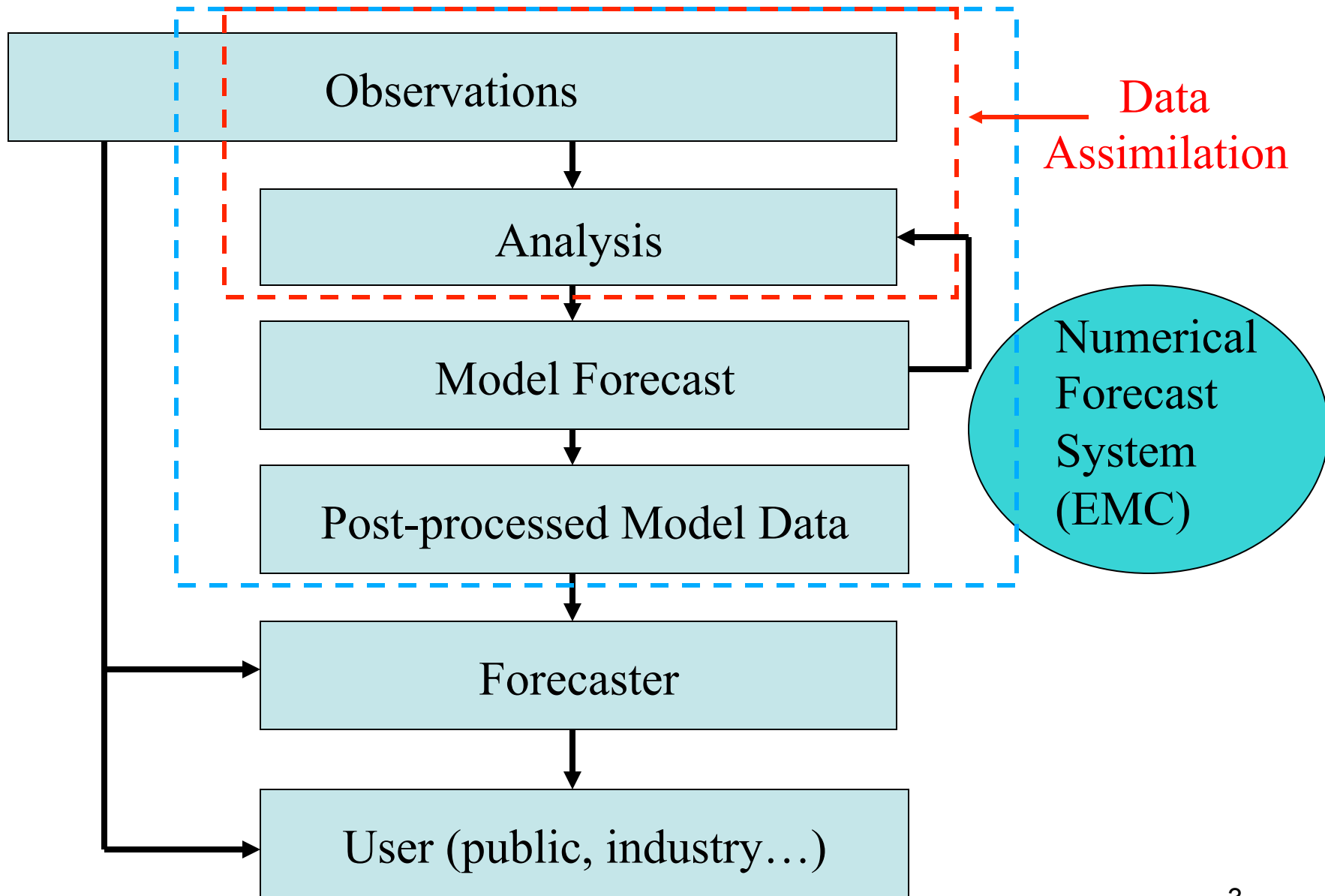
Outline



- **Introduction**
 - The numerical forecast process
 - EMC' s role as an operational transition organization
- **Global Weather and Climate**
- **Regional Weather and Air Quality**
- **Marine and Hurricane Systems**
- **Land and Space**
- **A few development challenges**
- **How to improve a forecast system***
- **Summary**

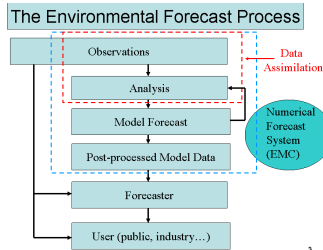
* Extra credit

The Environmental Forecast Process



Evolution of Forecast Capability - 1

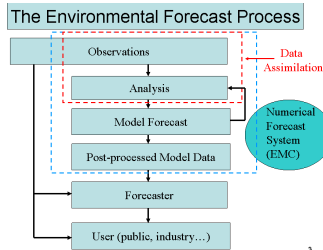
Atmosphere



- Weather forecast from Atmospheric System Only
- Forced by (constant) SST, Sea Ice and Solar Radiation
 - 1-5 days

Evolution of Forecast Capability - 2

Atmosphere



**1995:
QPF skill
requirements
force
Introduction of
land model**



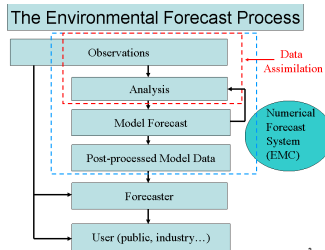
Land

- Weather forecast from Atmosphere-**Land** System
- Forced by (constant) SST, Sea Ice and Solar Radiation
- **1-15 days**

Evolution of Forecast Capability - 3

Atmosphere

Ocean



**2004:
Seasonal
forecast
requires
Ocean
coupling**

Land

- Seasonal forecast from Atmospheric-**Ocean**-Land System
 - Forced by constant Sea Ice and Solar Radiation
 - **1 day – 9 months**

Evolution of Forecast Capability - 4

Atmosphere

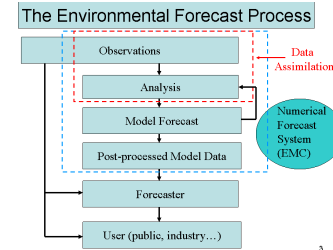
Ocean

**2010-13:
Changes in
Observed Sea Ice
Waves**



Cryosphere

Land



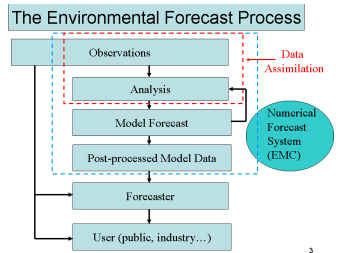
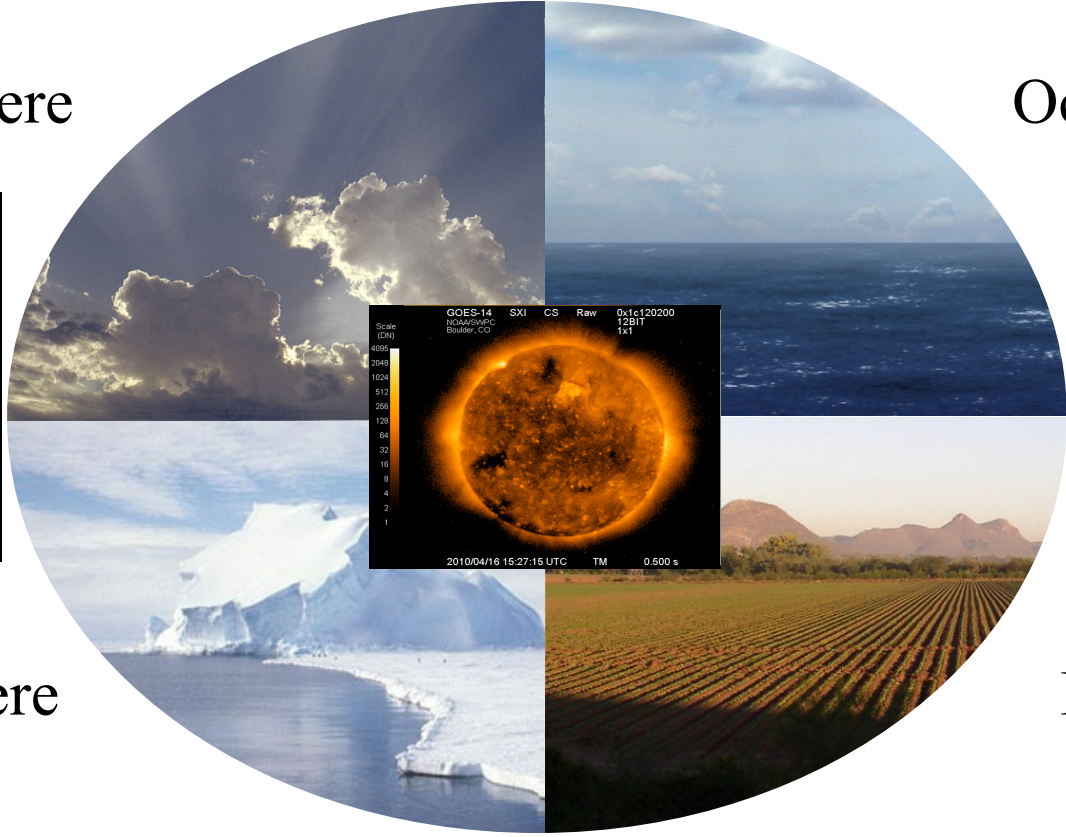
- Seasonal forecast from Atmospheric-Ocean-Land-Sea Ice System (2011)
 - 1day – 9 months
- Coupled hurricane-wave forecasts (2013+)

Evolution of Forecast Capability - 5

Atmosphere

Ocean

2013+:
Solar cycle
Aviation and
GPS Impacts



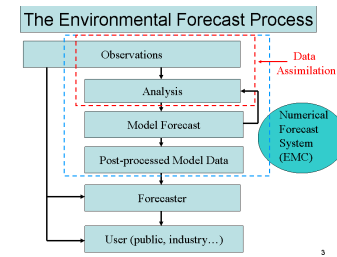
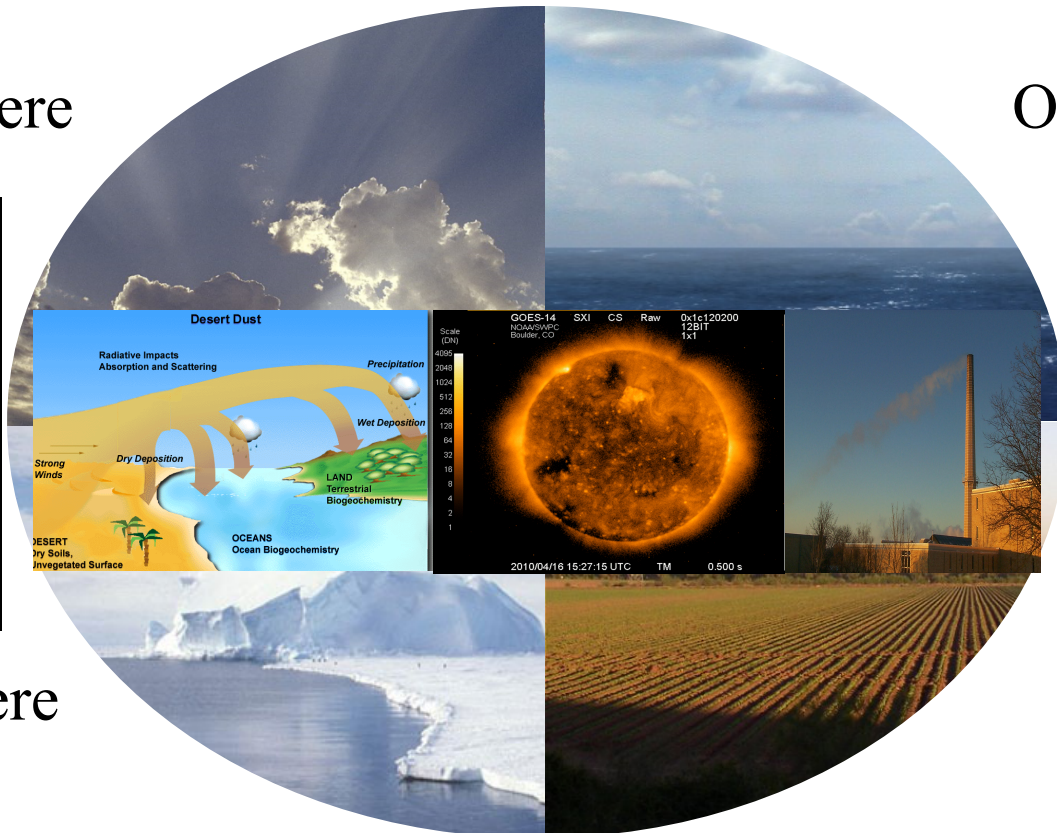
- Seasonal forecast from Atmospheric-Ocean-Land-Sea Ice System (2011)
 - **Solar Wind and Ionospheric State (2011+??)**
 - **1day – 2 years ??**

Evolution of Forecast Capability - 6

Atmosphere

Ocean

2015+:
Aerosols
Chemistry
Biogeochemical
Cycle
Hydrological
Services

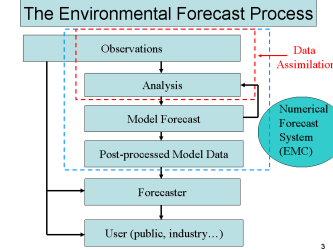


Cryosphere

Land

- Unified regional and Global Air Quality (2015+??)
- Atmospheric Constituents Analysis and Prediction (2017+??)
 - Biogeochemistry – carbon cycle (2020+??)
 - 1day – 10 years??

The EMC Mission.....



In response to operational requirements:

■ Develop and Enhance numerical guidance

- Improve NCEP's numerical forecast model systems via:

- Scientific upgrades
- Optimization
- Additional observations

45%

■ Transition operational numerical forecast models from research to operations

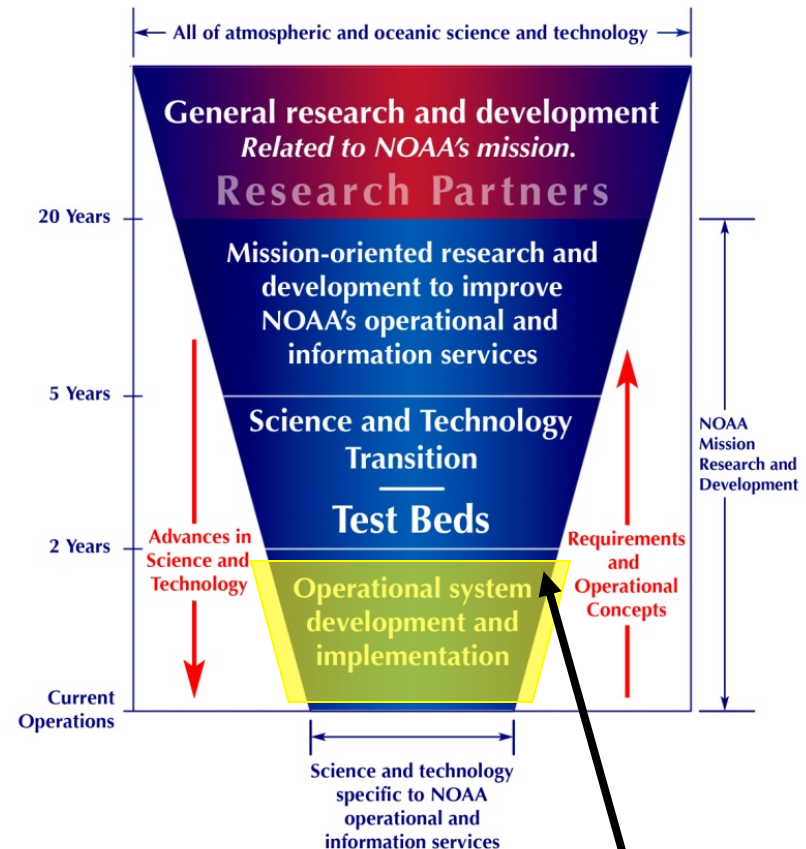
- Transform & integrate
 - Code
 - Algorithms
 - Techniques
- Manage and execute transition process including technical and system performance review before implementation

30%

■ Maintain operational model suite

- Ensure scientific correctness and integrity of operational forecast modeling systems
- Modify current operational system to adapt to ever-present external changes

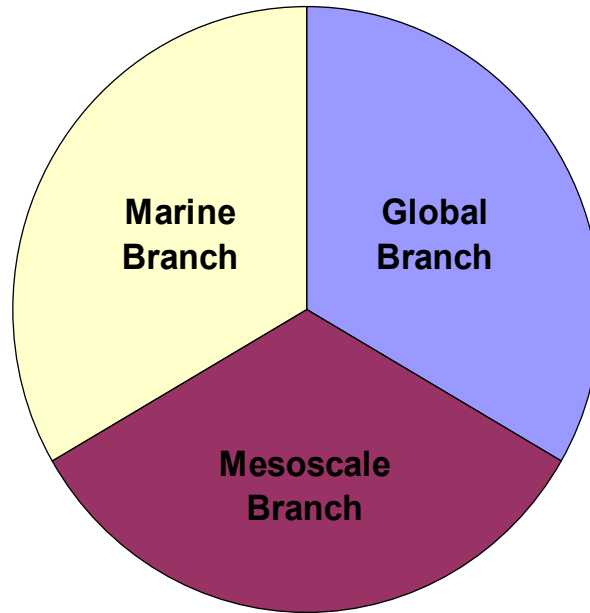
25%



EMC location within the funnel

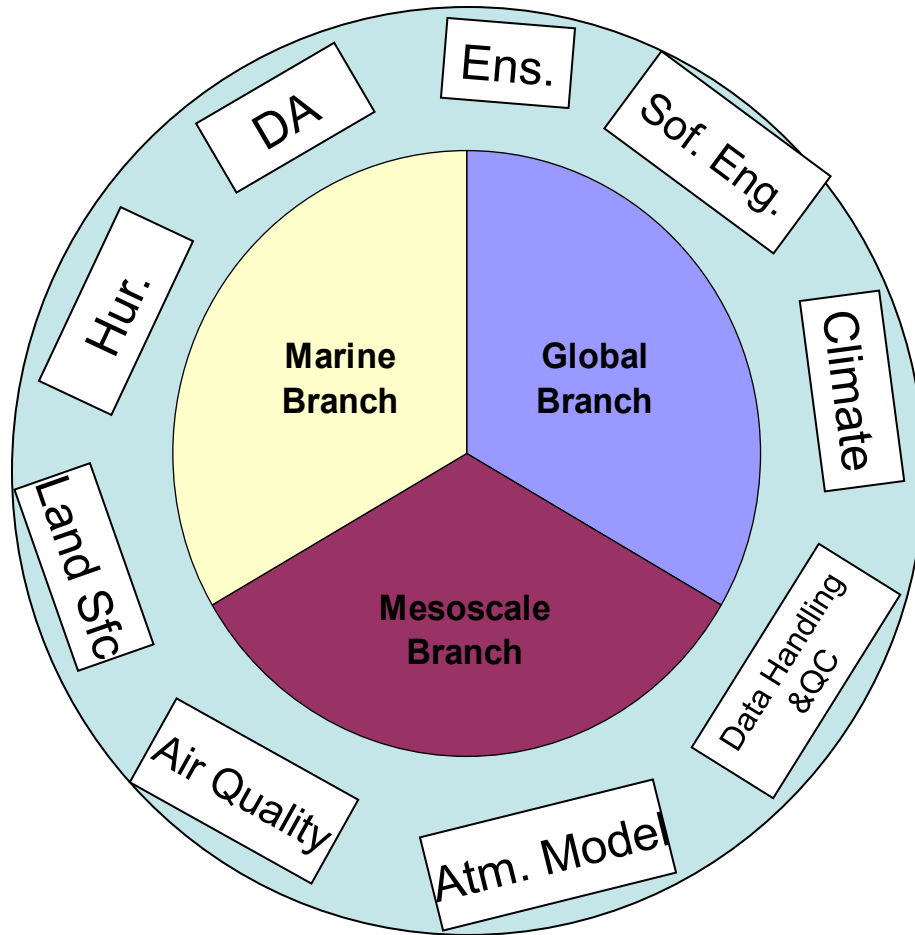
EMC Organizational Structure

EMC Branches and Teams



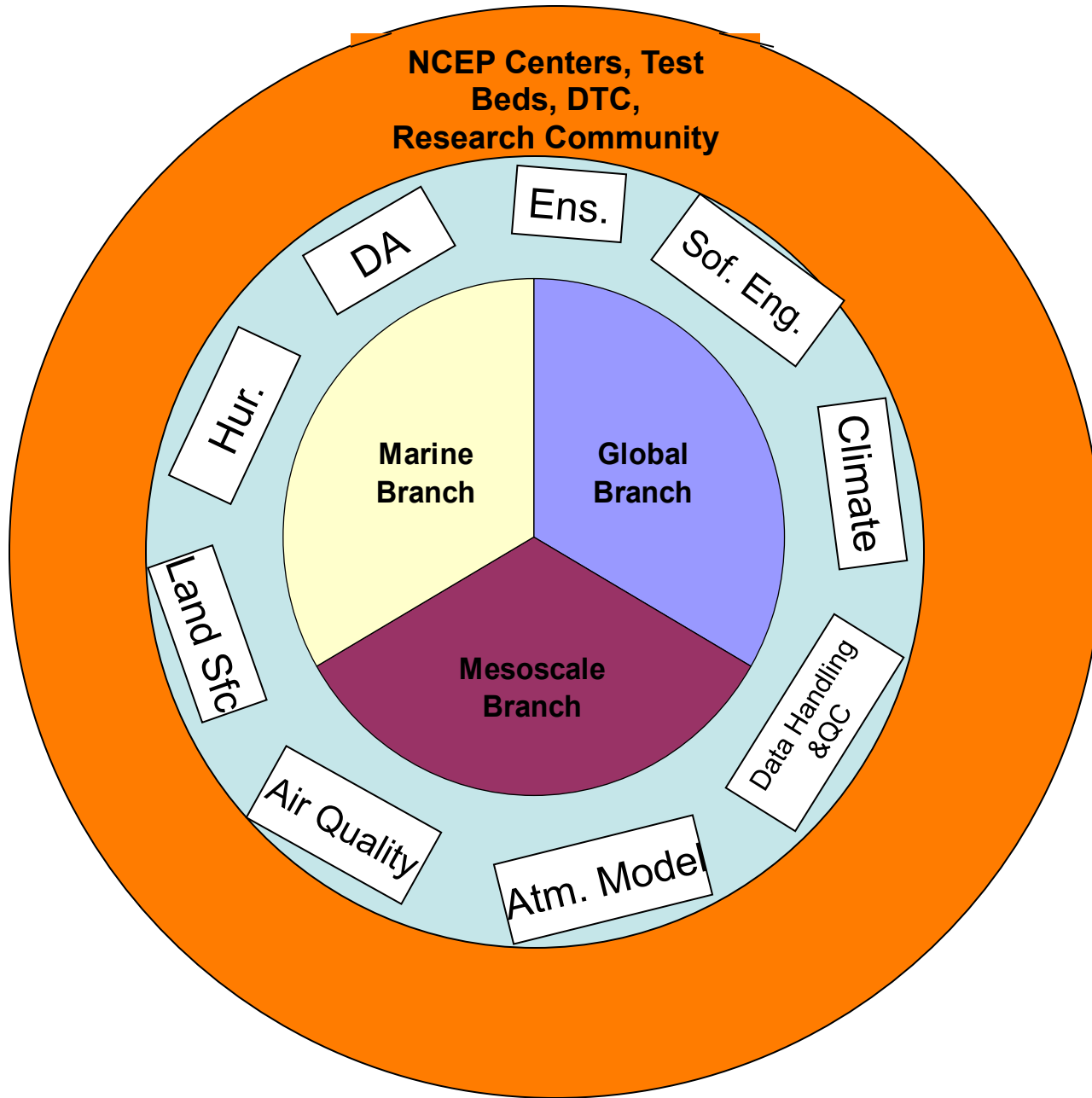
EMC Organizational Structure

EMC Branches and Teams



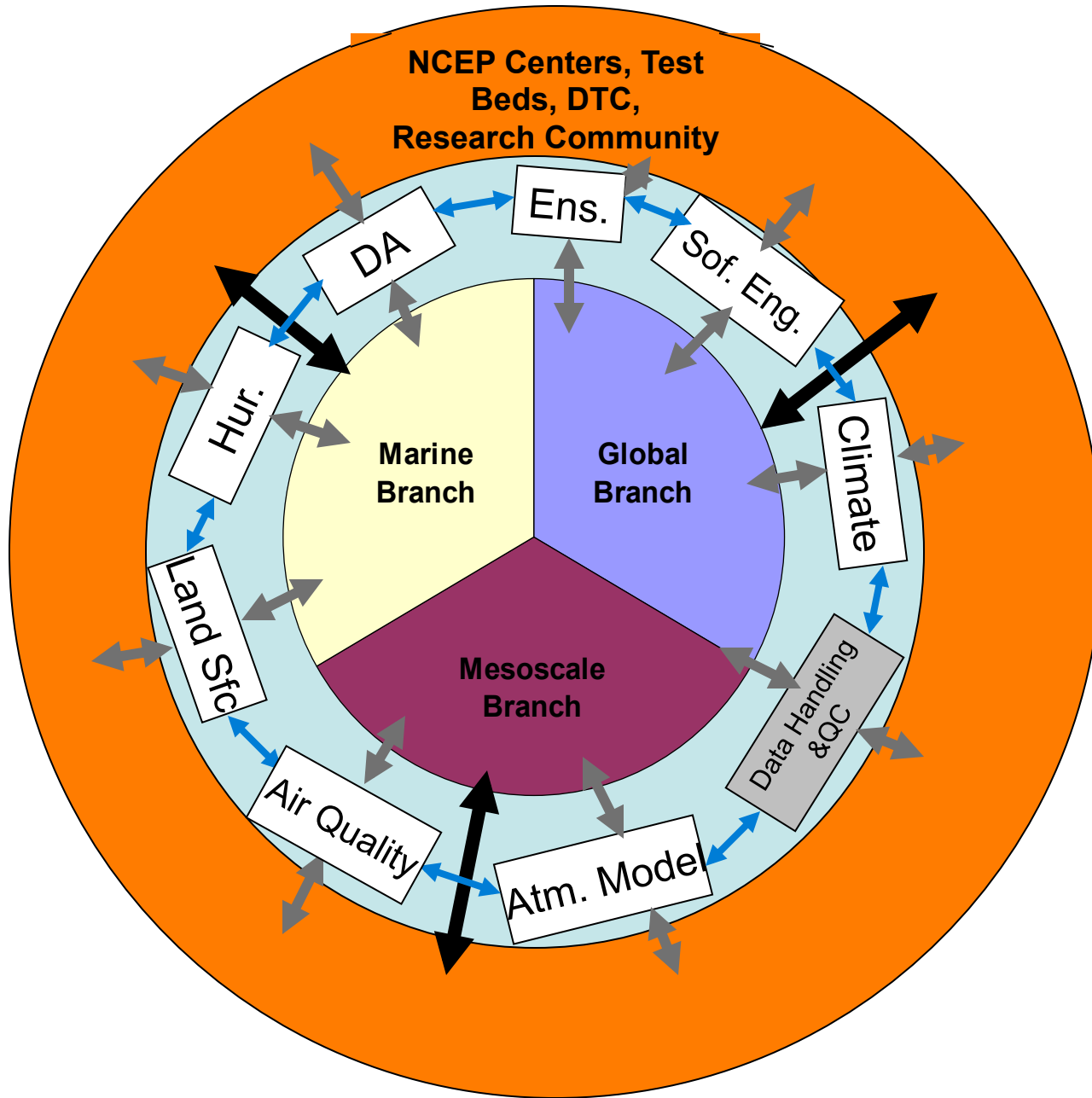
EMC Organizational Structure

EMC Branches and Teams and the External Community

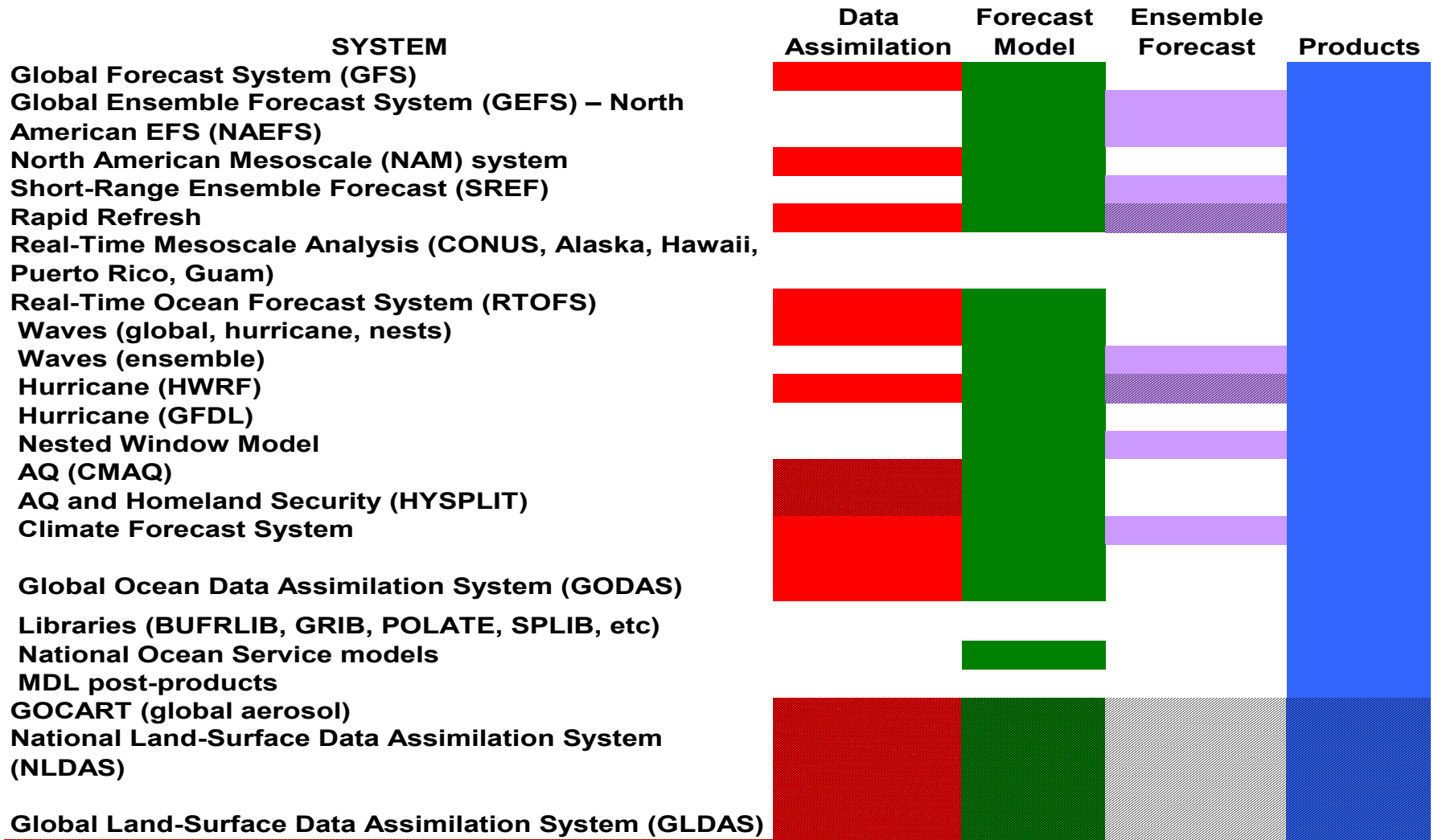


EMC Organizational Structure and Interactions

EMC Branches and Teams and the External Community



Production Suite “Major” Systems



Future

Total 24 Major Systems

For long term improvement, systems must be upgraded a minimum of once per year

Additional Product Development and Maintenance

Products

- SST analysis
- Sea ice analysis
- Hawaii run
- Downscaled Guidance (DGEX)
- On demand systems
 - Volcanic ash
 - Homeland security
- Verification
- Tracker systems
- Precipitation analysis
- NOMADS
- Specialized products (examples)
 - Vessel icing
 - Marine visibility
 - NAM DNG (SMARTINIT)

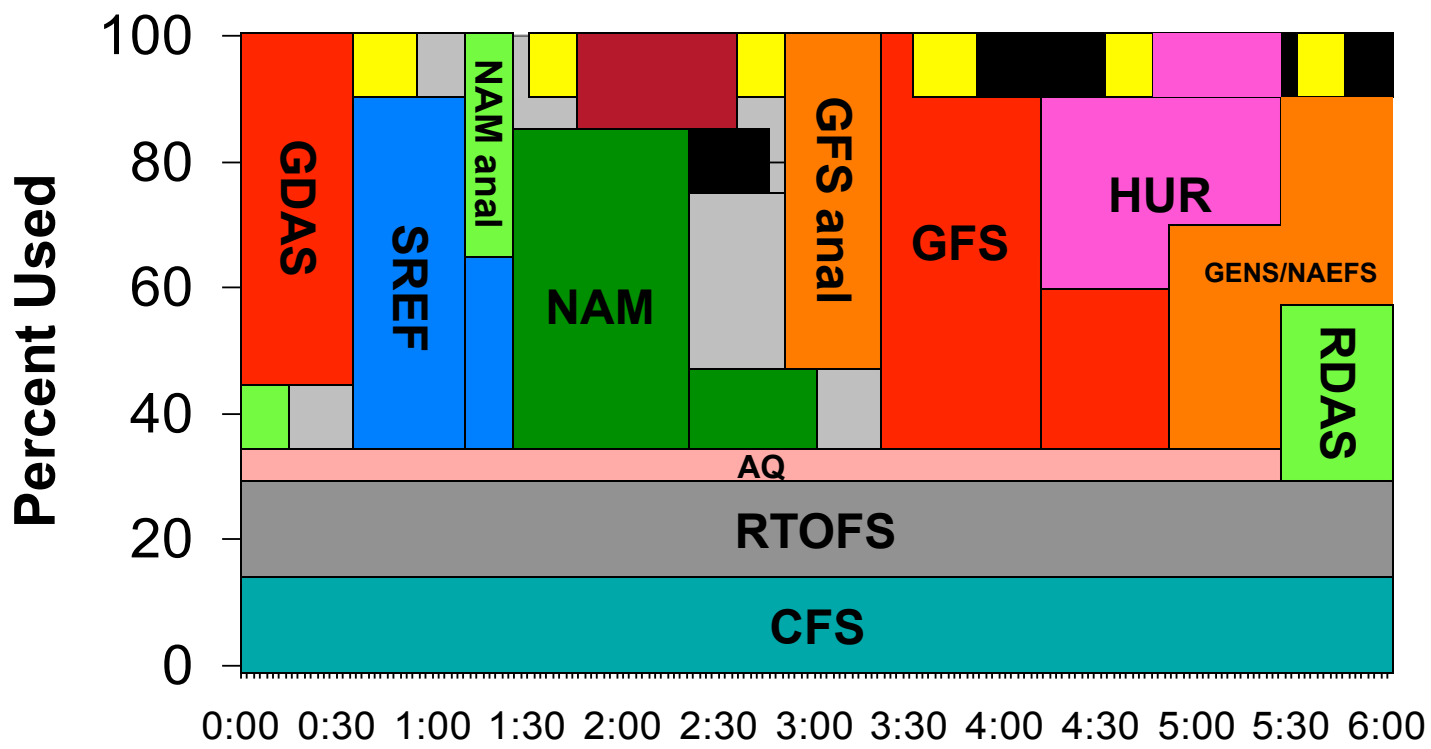
Maintenance

- Satellite data
- RTOFS initialization
- SST and other analyses
- QC
- Other system upgrades
 - “Use list”
- System errors
 - Data availability & reliability
 - Bug fixes
 - Execution errors

NCEP Production Suite Weather, Ocean, Land & Climate Forecast Systems

Current

■ Data processing



6 Hour Cycle: Four Times/Day

Global Weather and Climate

- GFS
- GENS
- CFS (V2)

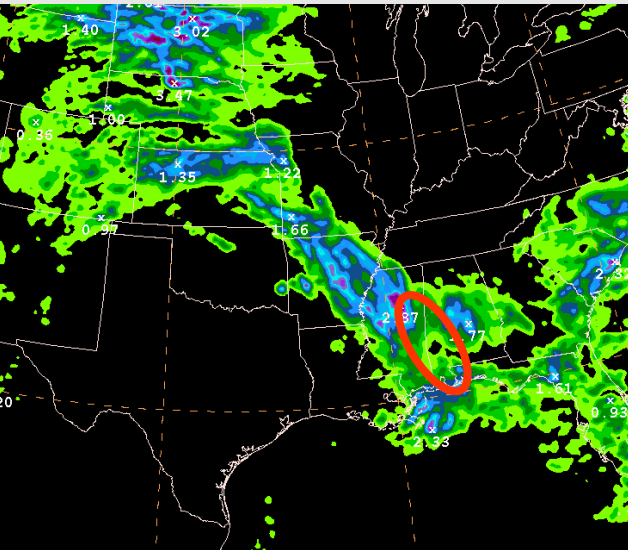
GFS Major Upgrade

Implemented July 2010

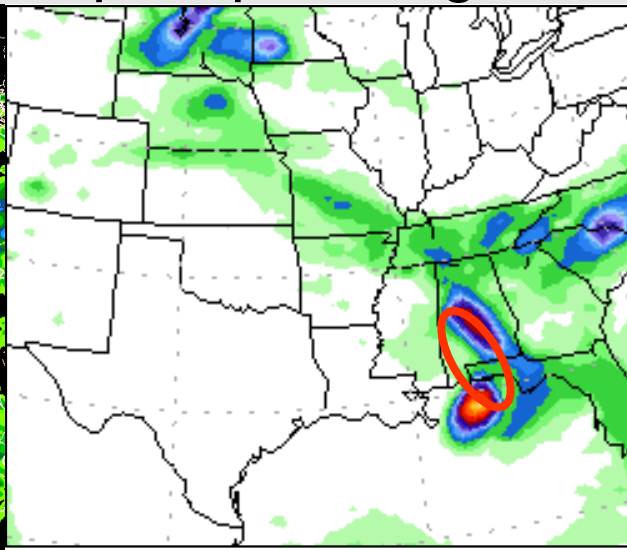
Jongil Han
Hua-Lu Pan

- ❑ **Modify GFS shallow/deep convection and PBL**
 - Detrainment from all levels (deep convection)
 - PBL diffusion in inversion layers reduced (decrease erosion of marine stratus)
- ❑ **GSI/GFS resolution increase**
 - T382 (~35km) to T574 (~28km)

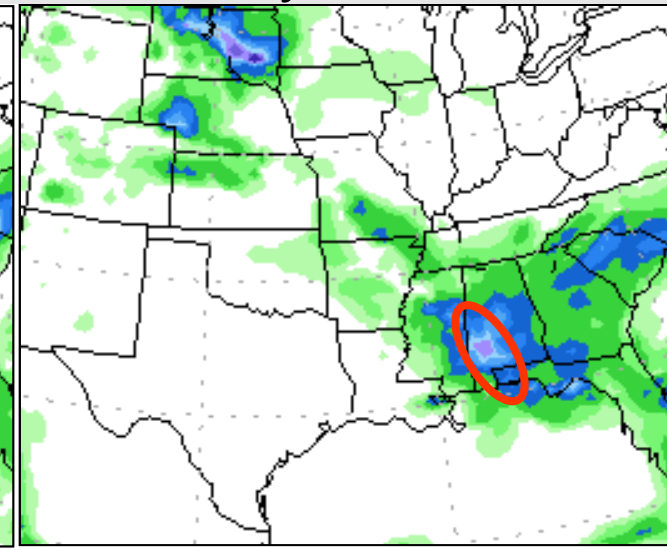
24 h accumulated precip ending 12 UTC 14 July 2009



Observed



Operational GFS



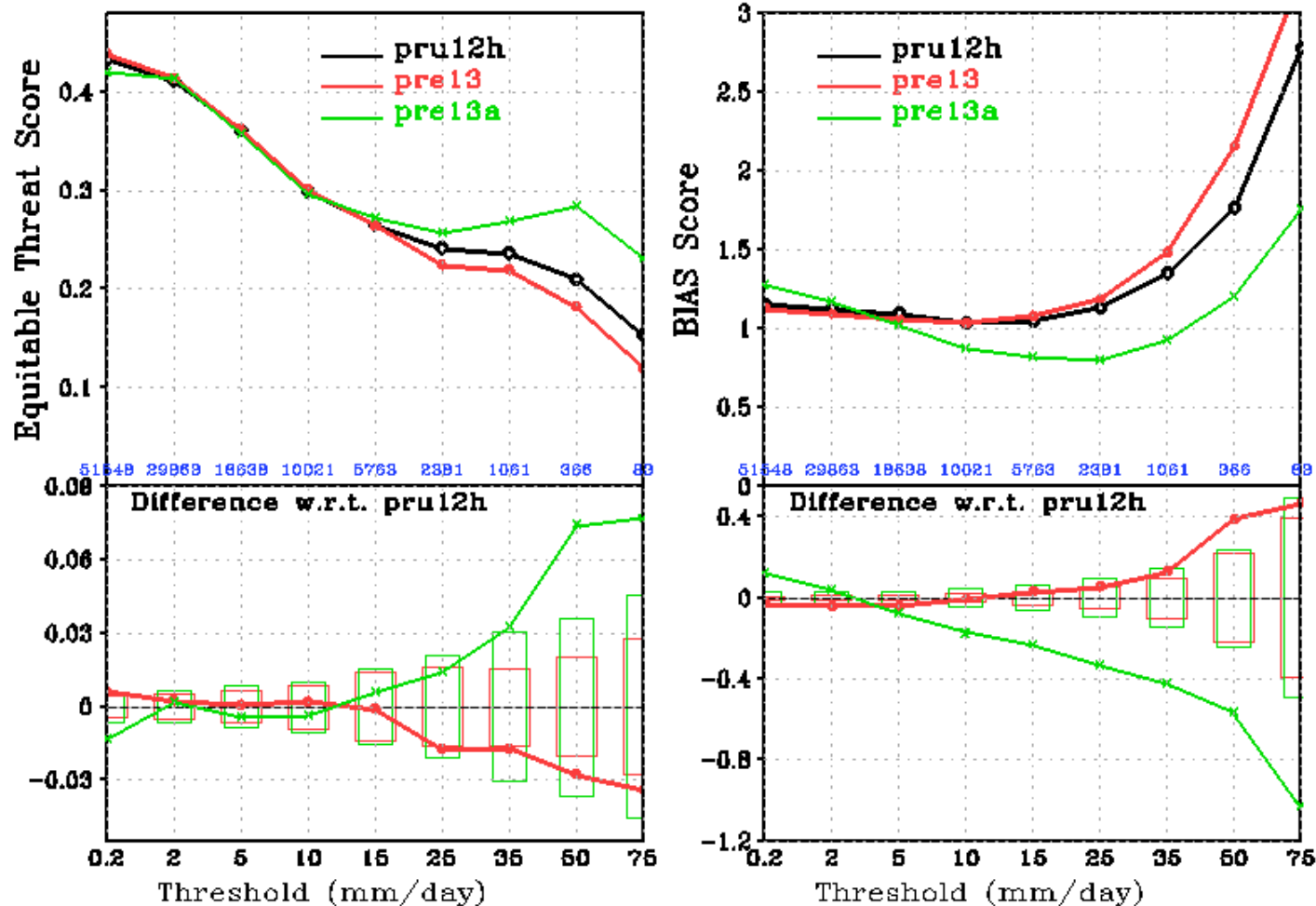
Upgraded Physics GFS

Updated GFS physics package reduces grid-point precipitation “bombs”

GFE Implementation Results

Precipitation Scores

CONUS Precip Skill Scores, f12-f36, 20jun2008-01nov2008



Differences outside of the hollow bars are 95% significant based on 10000 Monte Carlo Tests

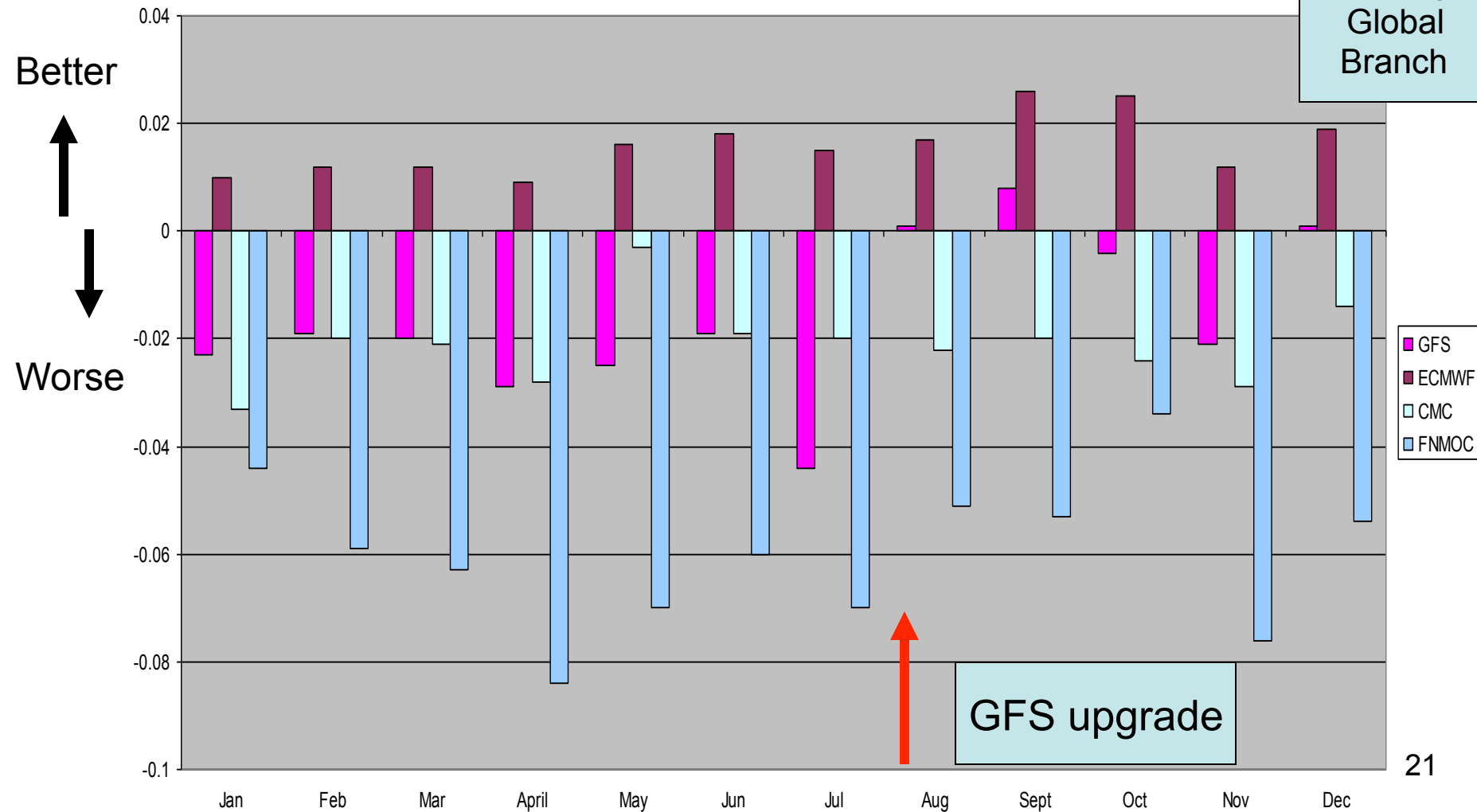
Red – without Shallow Conv

Green – With SC

GFS Major Upgrade (cont)

Day 5 NH 500 hPa AC Score Relative to UKMET

Moorthi
F. Yang
Global
Branch



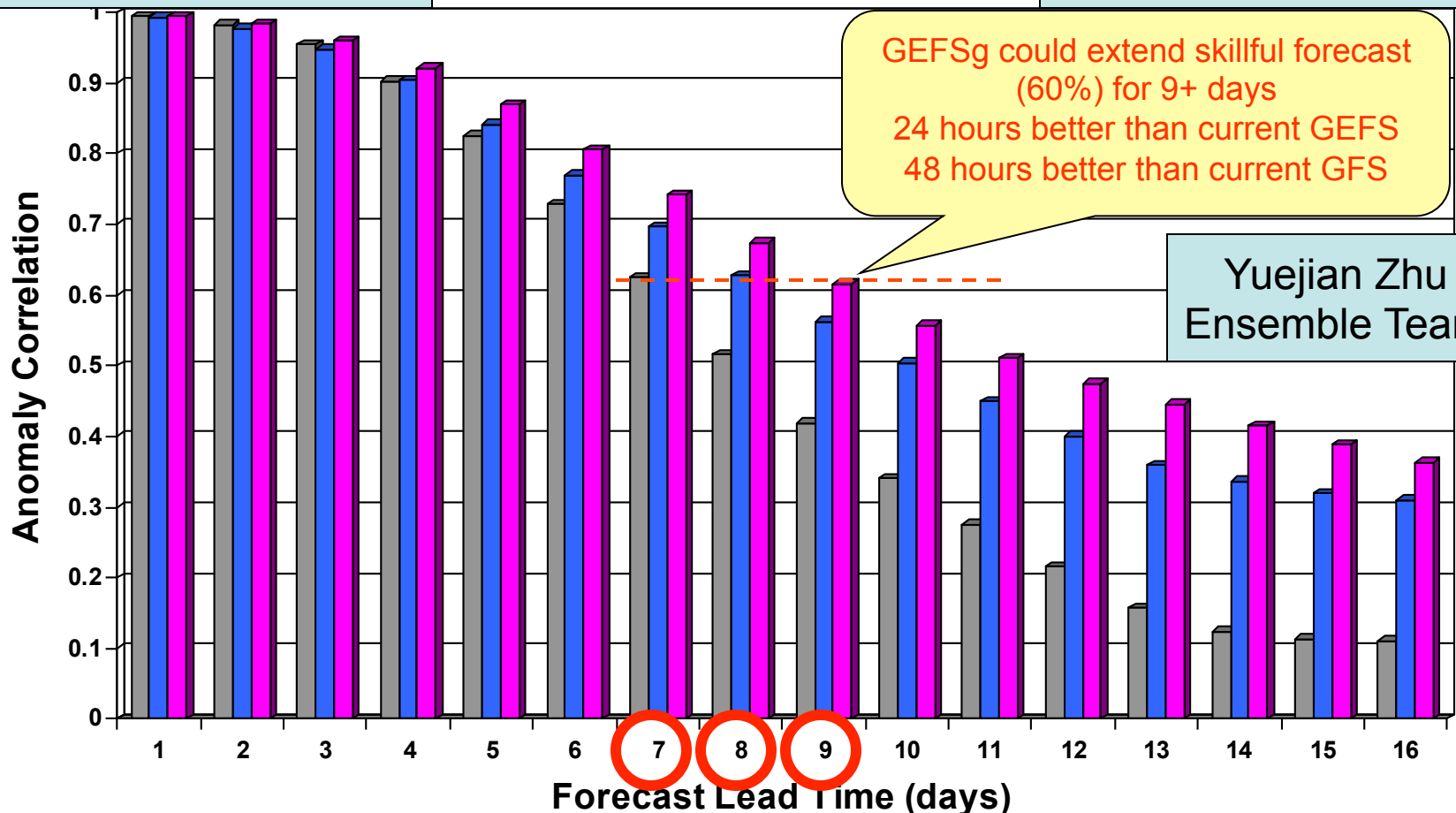
NCEP Global Ensemble Upgrade

100 → 70 km Res
Stochastic forcing
(not physical)

August 1st – September 30th 2007

■ GFS ■ GEFS ■ GEFSg

Implemented
Feb. 2010



GEFSg could extend skillful forecast (60%) for 9+ days
24 hours better than current GEFS
48 hours better than current GFS

Yuejian Zhu Ensemble Team

Q4FY11: T254/L42

Future:

GEFS initialization merged with Hybrid GDAS

North American Ens. Fcst. System (NAEFS)

With Canada, Mexico

National Unified Operational Prediction Capability

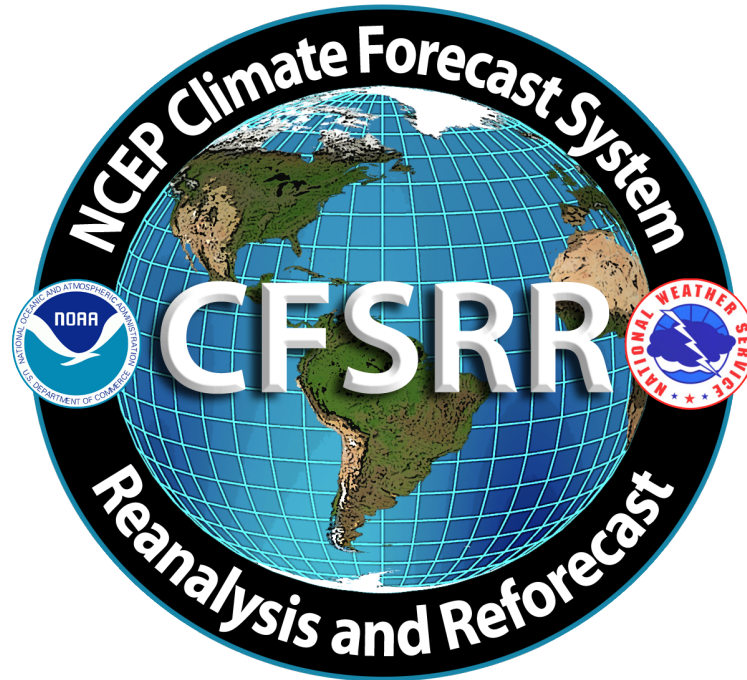
(NUOPC)

With Navy, USAF

THE NCEP CLIMATE FORECAST SYSTEM Version 2

Implementation Date: March 2011

cfs@noaa.gov



THE ENVIRONMENTAL MODELING CENTER
NCEP/NWS/NOAA



NCEP Climate Forecast System Reanalysis



System components:

- A new **Reanalysis** of the atmosphere, ocean, sea ice and land
- 31-year period (1979-2009)
- **Reforecast data set** provides stable calibration and skill estimates of the new system, for operational seasonal prediction at NCEP

Key differences with earlier NCEP Reanalysis efforts:

- Increased horizontal and vertical resolution (T382L64 vs T62L28) of the atmosphere (~38km)
- Background forecast generated from a **coupled atmosphere – ocean – sea ice – land system**
- **Radiance measurements** from the historical satellites **assimilated** (with spun up bias correction) in this Reanalysis vice retrievals
- **Variable CO2** from **forecast background** as well as observations and **observation operators**

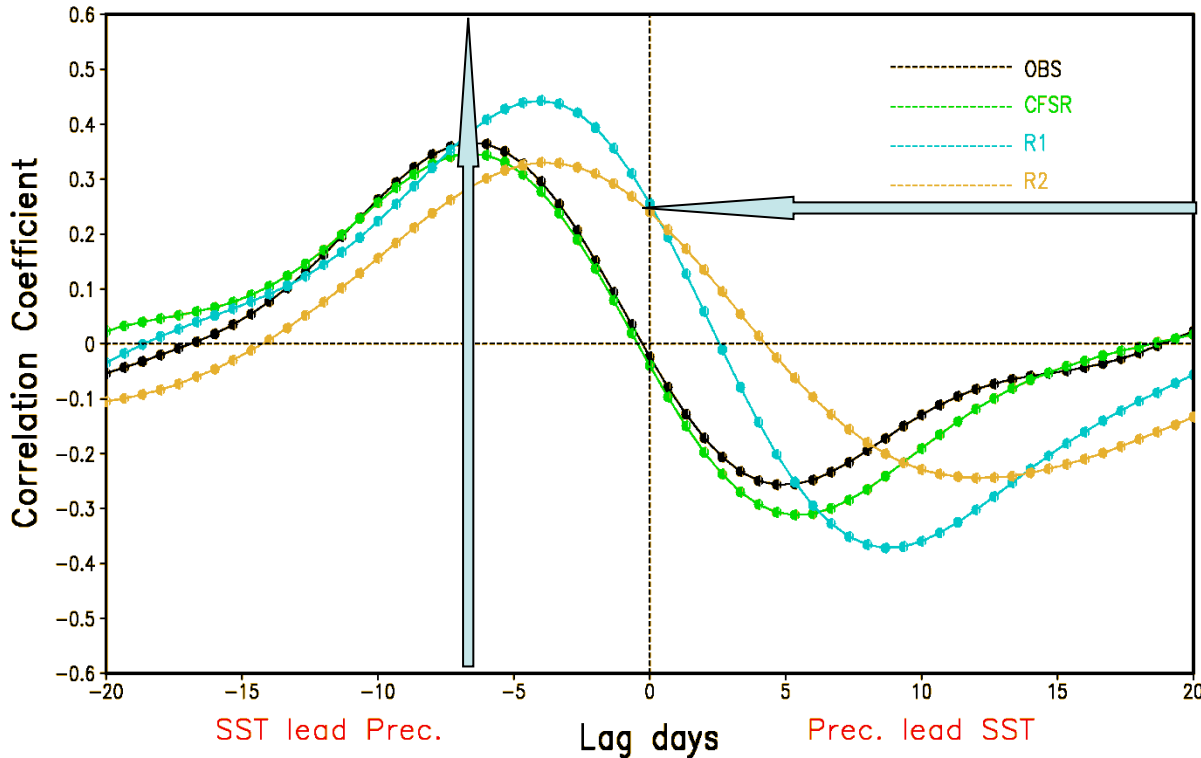
Climate Forecast System (CFS) Planned Upgrade for Q2FY11

Attribute	CFS v1 (Operational Configuration)	CFS v2 (Q1FY11)
Analysis Resolution	200 km	38 km
Atmosphere model	1995: 200 km/28 levels Humidity based clouds	100 km/64 levels Variable CO2 AER SW & LW radiation Prognostic clouds & liquid water Retuned mountain blocking Convective gravity wave drag
Ocean model	MOM-3: 60N-65S 1/3 x 1 deg.	MOM-4 fully global 1/4 x 1/2 deg. Assim depth 4737 m
Land surface model (LSM) and assimilation	2-level LSM No separate land data assim	4 level Noah model GLDAS driven by obs precip
Sea ice	Climatology	Daily analysis and Prognostic sea ice
Coupling	Daily	30 minutes
Data assimilation	Retrieved soundings, 1995 analysis, uncoupled background	Radiances assimilated, 2008 GSI , coupled background
Reforecasts	15/month seasonal output	25/month (seasonal) 124/month (week 3-6)

SST-Precipitation Relationship in CFSR

Precipitation-SST lag correlation in tropical Western Pacific

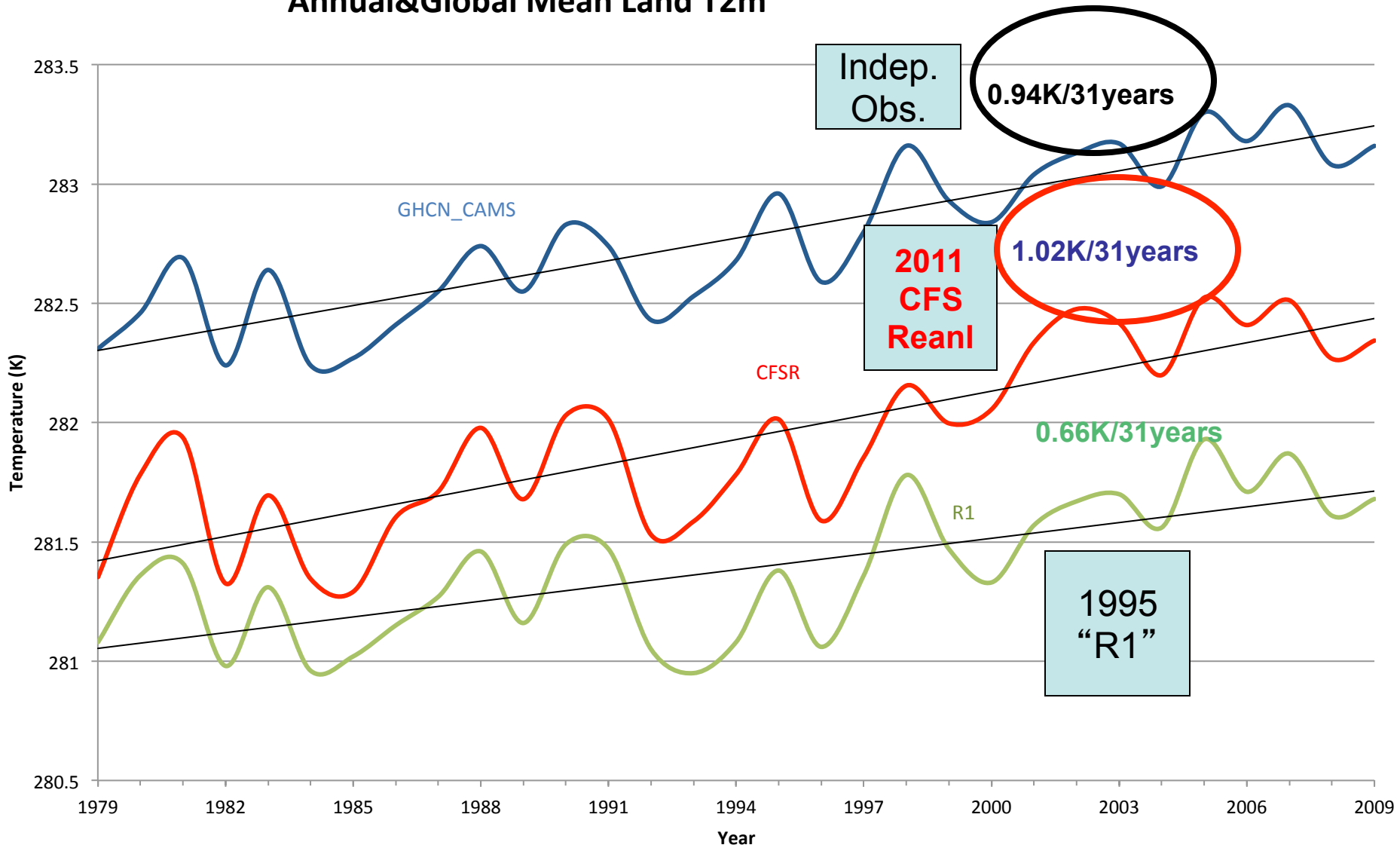
Lag Correlation of Prec. and SST over Western Pacific (winter)



Response of Prec. To SST increase : warming too quick in R1 and R2
simultaneous positive correlation in R1 and R2

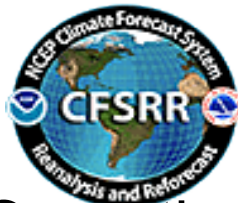
Courtesy: Jiande Wang

Annual & Global Mean Land T2m



- ➔ CFSR has less bias than R1, relative to GHCN_CAMS
- ➔ Upward trend in CFSR larger than in R1, more like GHCN_CAMS

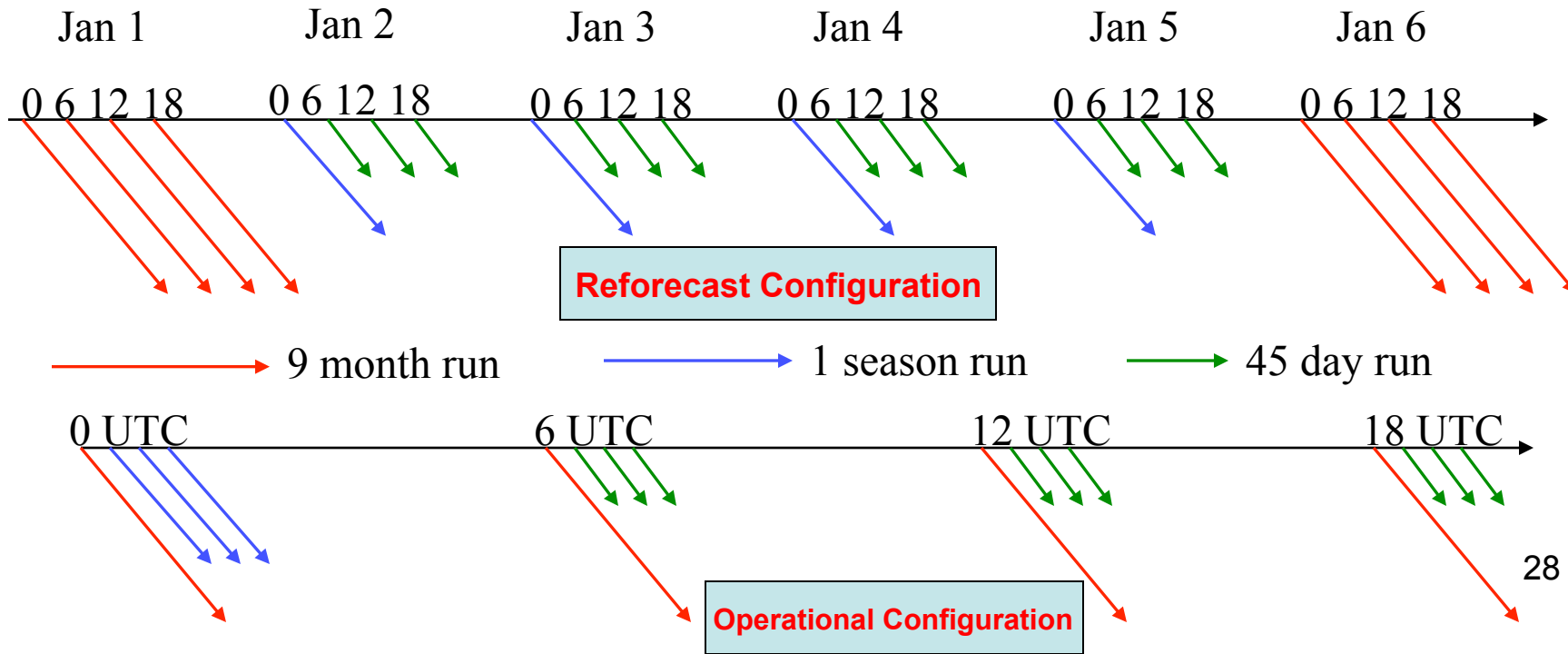
NWS/CPC
H. Vandendool



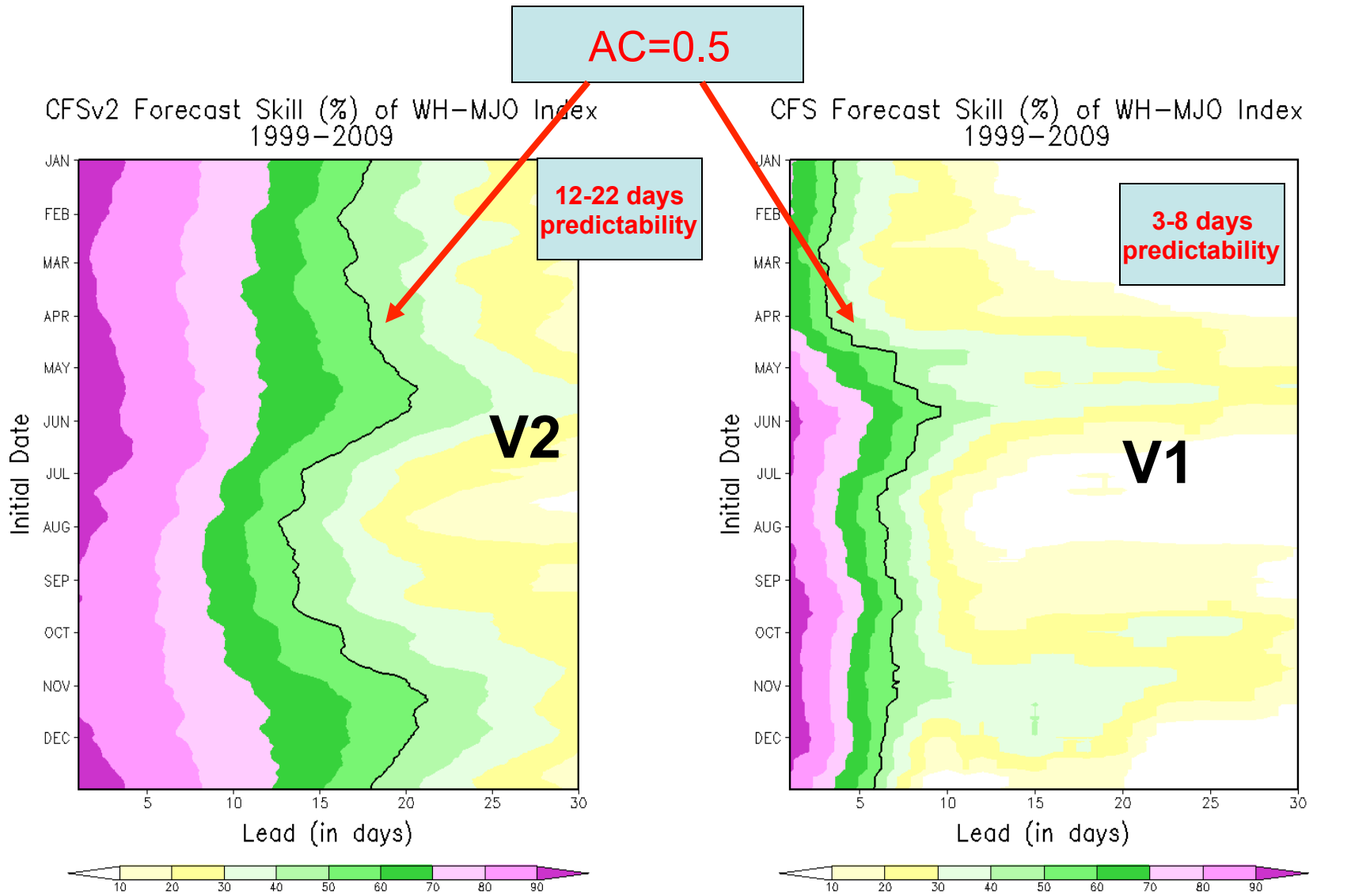
Reforecast and Operational Configurations for CFSv2 (T126L64)

- **Reforecasts support CPC operational forecasts**

- **Multi-Seasonal calibration (9 months)**
 - 1982-2010
 - Longer-term seasonal predictions (ENSO, etc)
- **123-day (1 season)**
 - 1999-2010
 - Calibrates first season predictions for hydrological forecasts (precip, evaporation, runoff, streamflow, etc)
- **45-day (1-month)**
 - 1999-2010
 - Supports week3-week6 predictions of tropical circulations (MJO, PNA, etc)



Forecast Skill of WH-MJO index



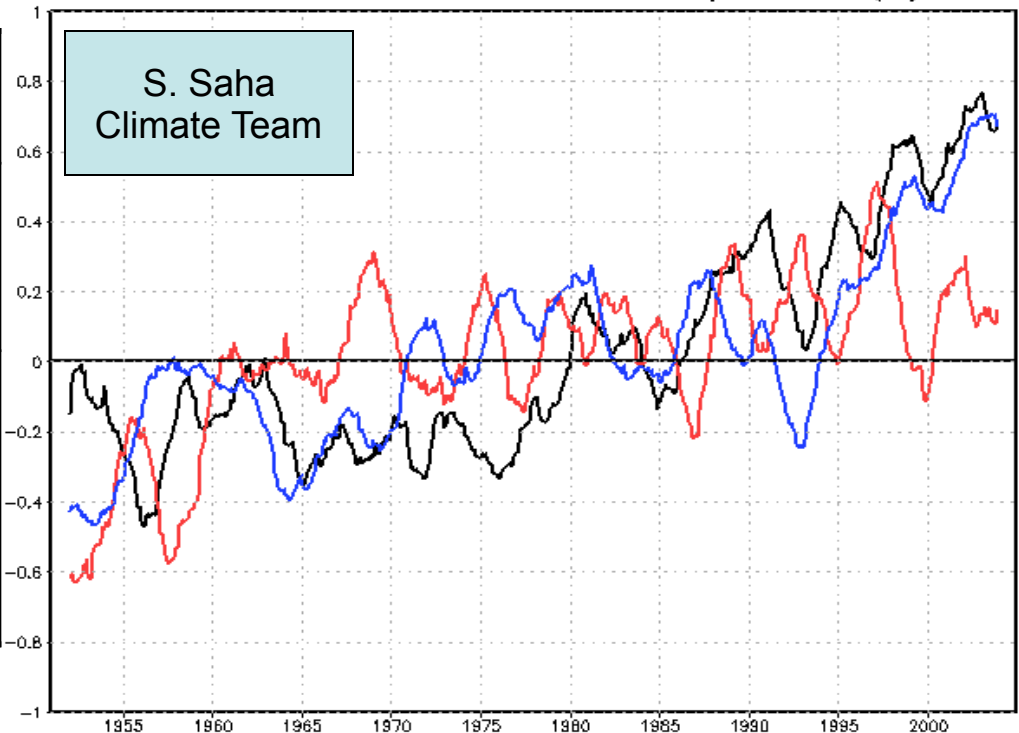
Courtesy Qin Zhang – NCEP/CPC

Investigation of ISI-Decadal linkages

- CFS capability to recreate decadal temperature profile
- Adopted by COLA for decadal prediction research and India for operational seasonal prediction

— OBS	CPC Analysis (Fan and van den Dool, 2008)
— CTRL	CMIP run with 1988 CO2 settings (no variations in CO2, current operations)
— CO2	Ensemble mean of 3 NCEP CFS runs in CMIP mode – realistic CO2 and aerosols in both troposphere and stratosphere

Glb Mean LAND ONLY 2m-Temp Anom (C)

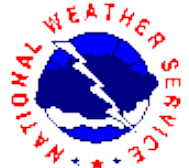


Processing: 25-month running mean applied to the time series of anomalies (deviations from their own climatologies)

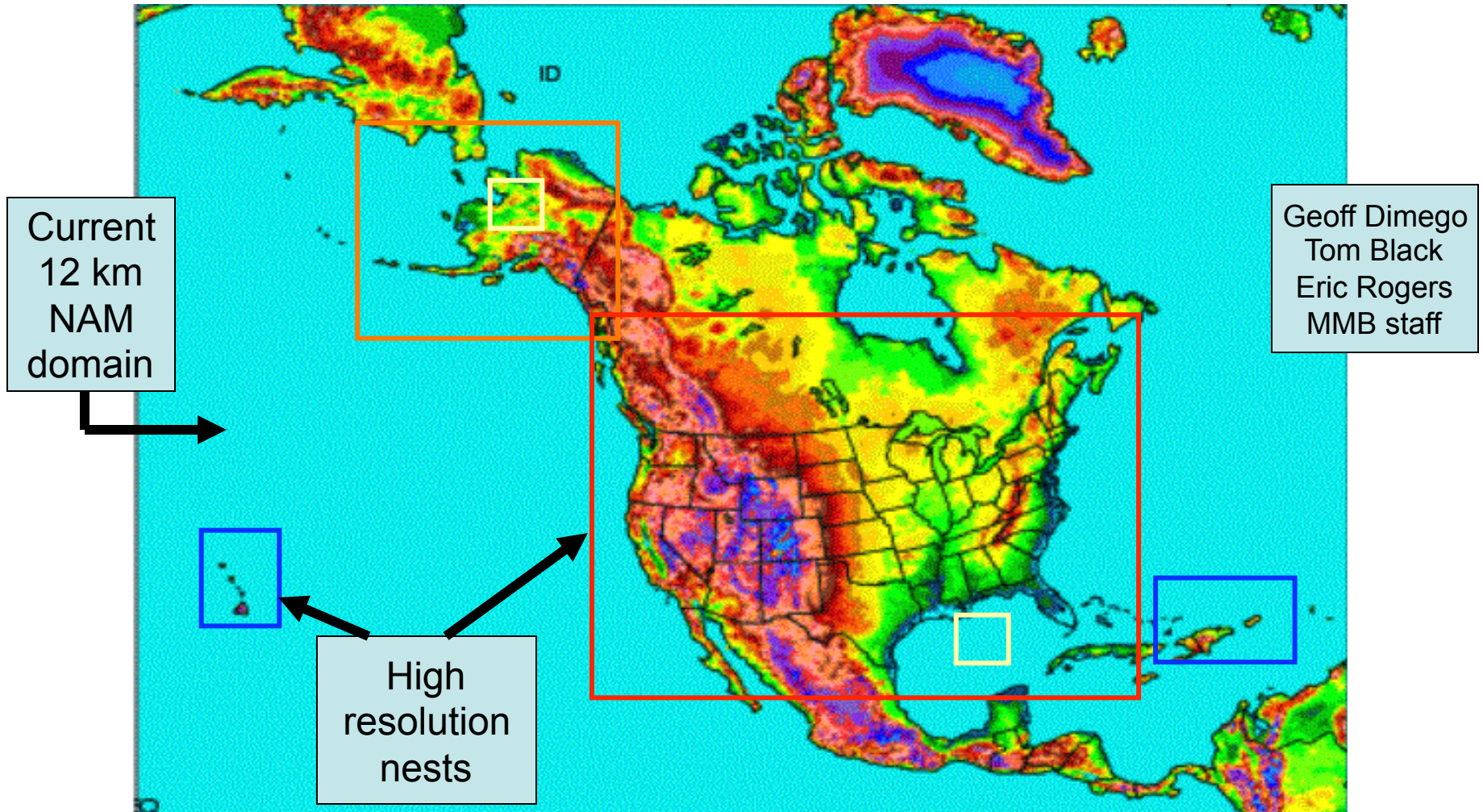
Testing CFS V2 with CMIP Runs (variable CO2)

Regional Weather and Air Quality

- NAM
- RUC
- HRW
- SREF
- RTMA
- AQFS



Continental → Local Model Strategy



Nests run concurrently to outer domain
Single software infrastructure for all operational systems (NEMS)

RUC → Rapid Refresh

Implementation Planned Q4FY11

RUC

- Non-WRF RUC model
- RUC 3DVAR analysis

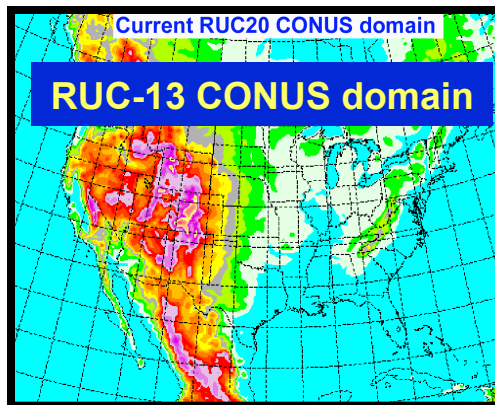


Rapid Refresh (RR)

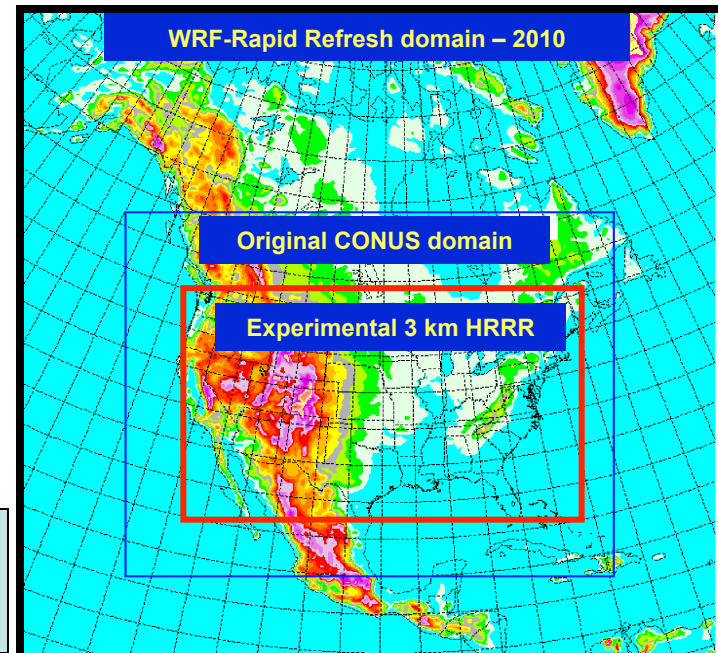
- **WRF-based ARW**
- **NCEP's GSI analysis**
- **Expanded Domain**
 - ~6 times bigger
 - Includes Alaska
- Experimental 3 km HRRR runs at ESRL/GSD

RUC & RR

- 24/Day = hourly update
- Forecasts to 18 hours
- 13 km horizontal resolution



Stan Benjamin
Steve Weygandt



HYBRID HRW-SREF Postprocessing 3 hour accumulated precipitation

Prototype
High resolution
Multi-model
Ensemble-based

ARW

NMM

100330/0600V030 SFC P03I

100330/0600V030 SFC P03I

Jun Du
Matt Pyle

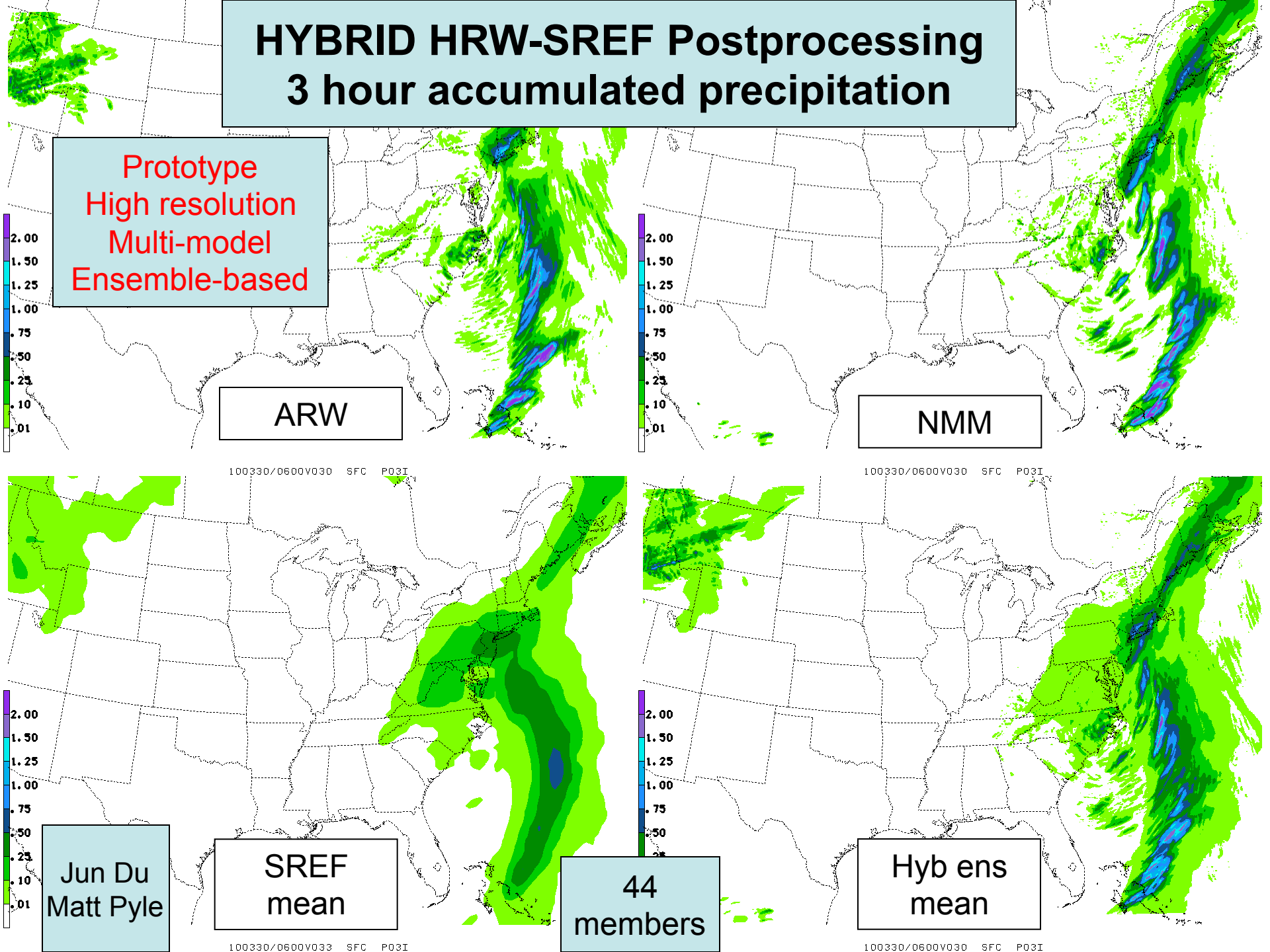
SREF
mean

44
members

Hyb ens
mean

100330/0600V033 SFC P03I

100330/0600V030 SFC P03I



Very Short Range Ensemble Forecast (VSREF) System

Binbin
Zhou

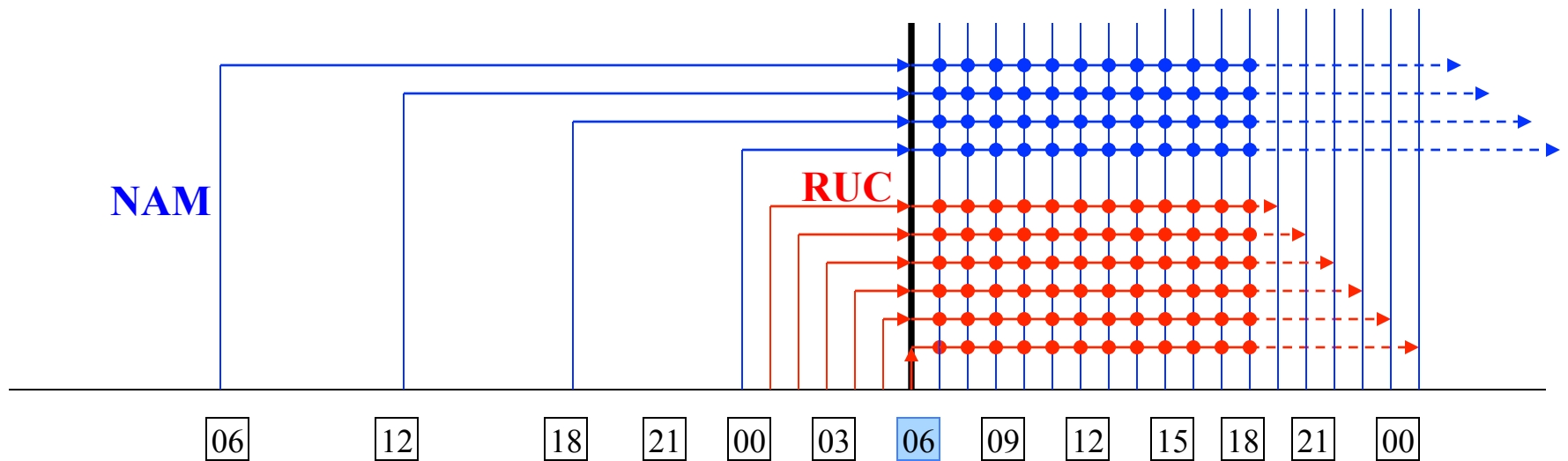
• **Example: Ensemble member combination for 06Z cycle run**

4 NAM cycles, weighted 0.7, 0.5, 0.3, 0.1, respectively

6 RUC cycles, weighted 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, respectively

Forecast hour extended to 12 hr (with extension of RUC forecasts to 18hr)

NAM cycles always older than RUC → VSREF gives more weight to RUC

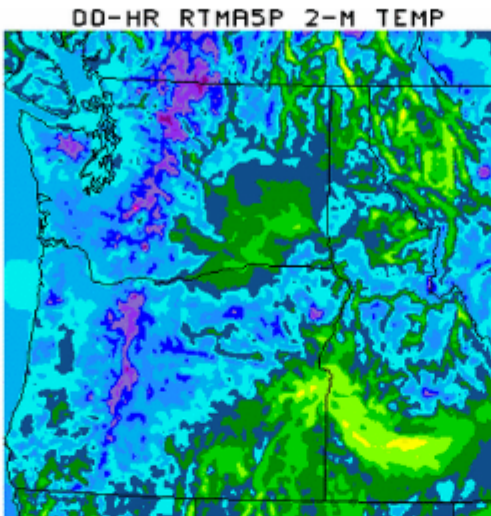
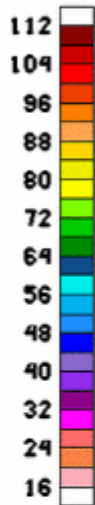


Soon-to-be-known-as the NARRE-TL for Time Lagged NARRE

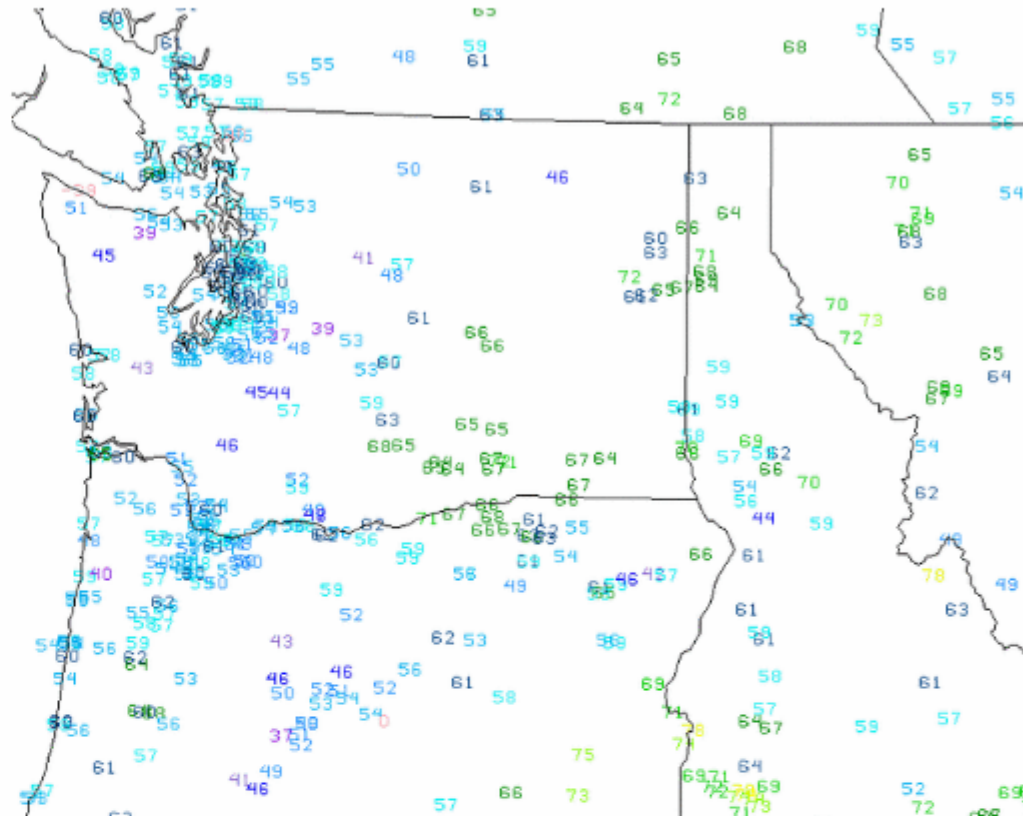
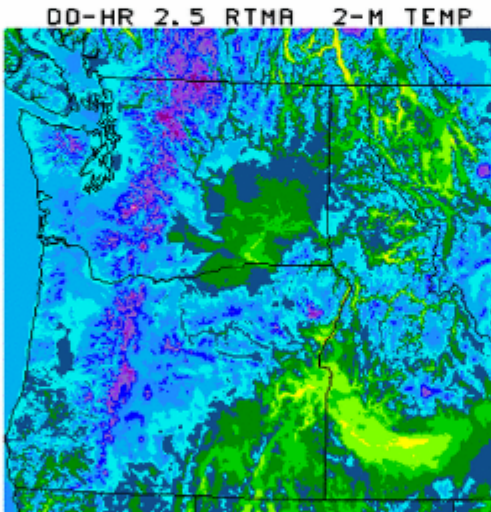
RTMA 2.5 km (bottom) vs 5 km (top) Implemented Sept. 2010

Manuel
Pondeva
Data
Assimilation
Team

<http://www.emc.ncep.noaa.gov/mmb/rtma/2.5/01z/>



ANALYSIS VALID 01Z 06/16



Upgrades in response to Field requests
Bias corrected background
Improved analysis techniques
Quality Control

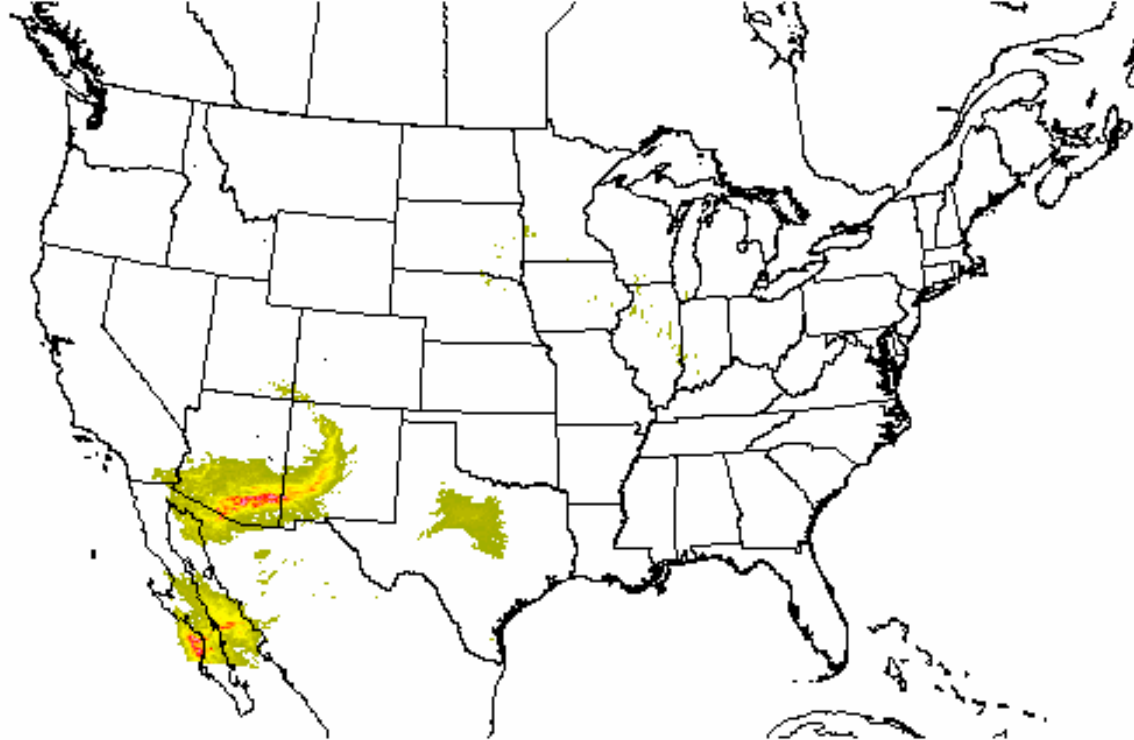
Regional Forecasting Strategy

- NAM and RUC (RR) are separate systems with different dynamics and physics
- Strategy
 - Combine NAM, RR and SREF to form hourly updated ensemble-based IC and forecasts
 - Uncertainty determined by ensemble diversity (using hybrid ensemble postprocessing)
 - Initial & Lateral Boundary conditions
 - Dynamics & Physics
 - Combined system can evolve with rapidly developing science of underlying ensemble-based data assimilation and model development
 - North American Rapid Refresh Ensemble (NARRE)
 - Initially ~6 member ensemble made up of equal numbers of NMMB- & ARW-based configurations
 - 12 km system
 - Combined with SREF to create 27 member ensemble
 - Hourly updated with forecasts to 24 hours, except at 00, 06, 12, 18 UTC (84 h)
 - High Resolution Rapid Refresh ENSEMBLE (HRRRE)
 - Each member of NARRE contains 3 km nests
 - CONUS, Alaska, Hawaii & Puerto Rico/Hispaniola
 - The NMMB & ARW control runs initialized with radar data & other hi res obs
 - Provide NextGen Enroute and Terminal guidance with nesting over CONUS and major airports
- Mature HRRRE system capabilities (~2020)
 - Provides full Probability Density Function at 3 km resolution
 - Provides a vehicle to improve assimilation capabilities using hybrid technique with current & future radar & satellite
 - Addresss NWS requirement for Warn-on-Forecast capability as resolutions evolve towards ~1 km
- **Computing shortfall must be addressed**

2010 Air Quality Prediction

Ozone, Smoke Operational Nationwide; Dust Testing

- **Ozone: Expanded Forecast Guidance to Alaska and Hawaii domains in NWS operations (9/10)**
- **Smoke: Expanded Forecast Guidance to Hawaii domain in NWS operations (2/10)**
- **Aerosols (6/10)**



1Hr Column Dust (micrograms/m³) Wed Mar 10 2010 2AM EST

Developmental testing (Wed Mar 10 2010 07Z)

National Digital Guidance Database

06z model run Graphic created-Mar 15 10:43AM EDT

NWS
OST
AQ
Program
(I. Stajner)
J. McQueen

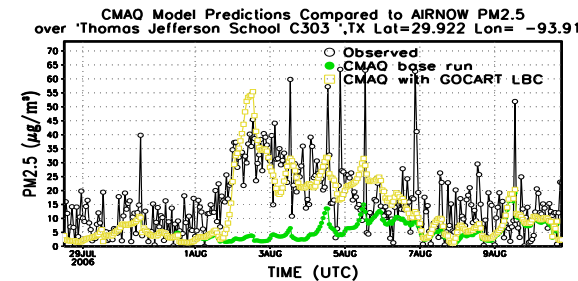


GOCART Global Aerosol

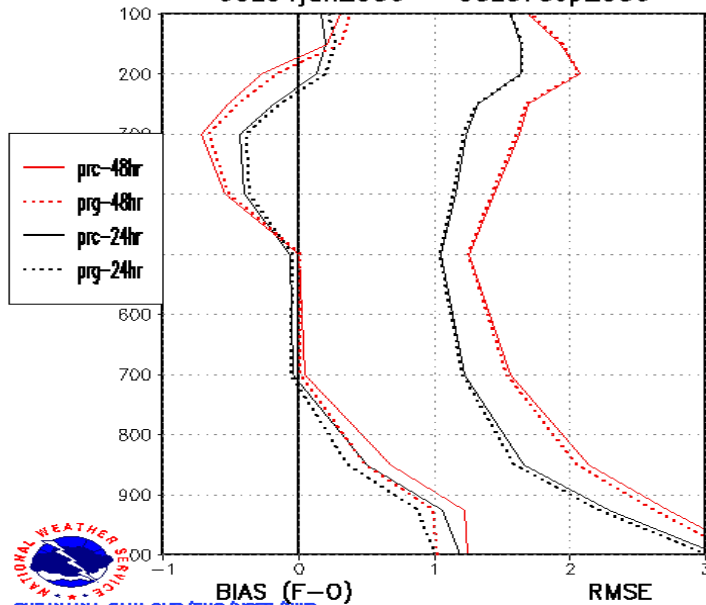
J. McQueen
S. Lu
AQ Team

- Collaboration with NASA/GMAO (daSilva et al)
- Supported by NASA Applied Science Program and JCSDA
- ESMF-based software engineering
- Verification with AERONET and satellite data
- Will

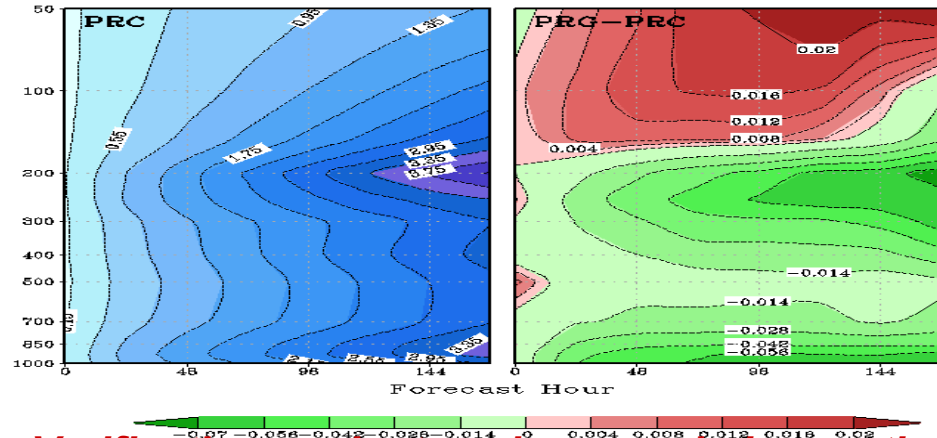
- Provide boundary conditions for regional AQ
- Improve global radiation budget (Sahara dust....)
- Impact tropical prediction
- Include biomass burning
 - Testing NESDIS Global Biomass Burning Emissions Product (GBBEP) dataset and NASA QFED version 2



North America Temp Fits to RAOBS
00z04jun2006 – 00z07sep2006



RMS: 20060604–20060907 Mean for T G2/NHX 00Z



Verification against analyses and observations indicates a positive impact in temperature forecasts due to realistic time-varying treatment of aerosols.

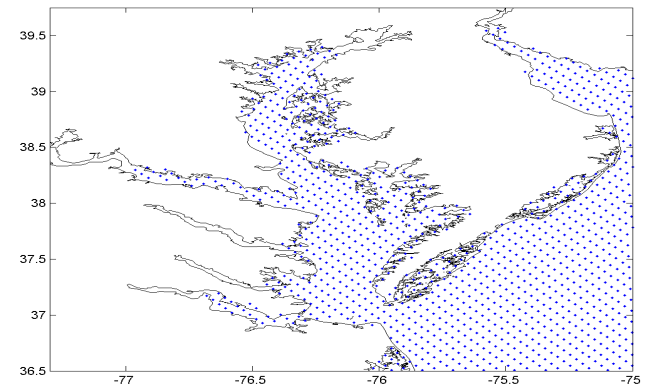
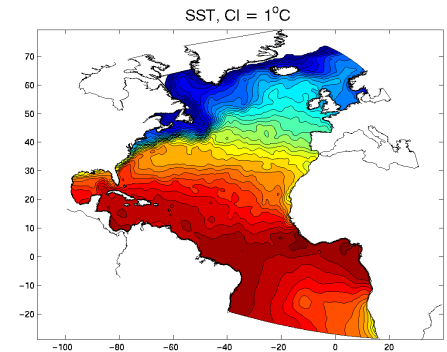
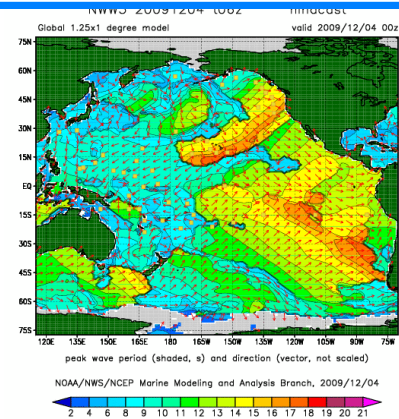


Marine and Hurricane

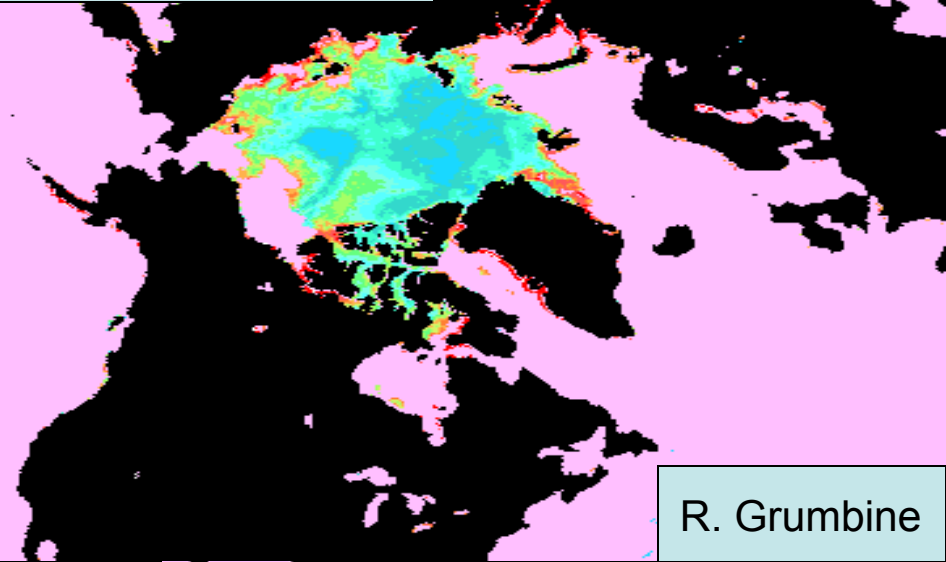
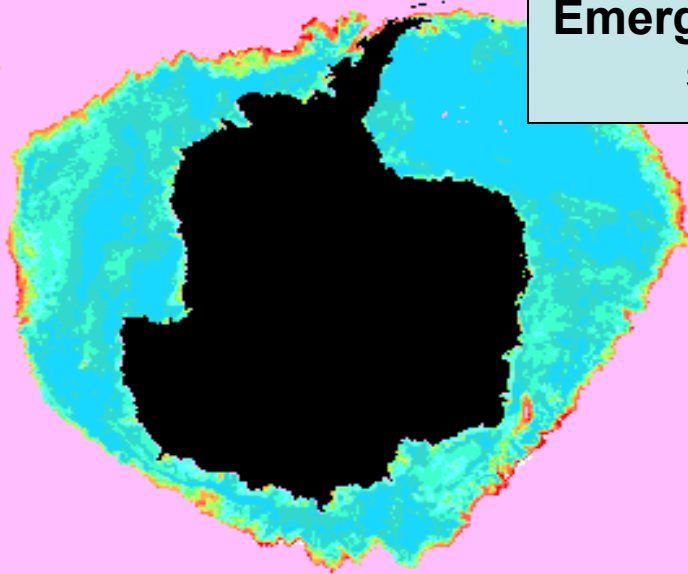
- Waves
- Sea Ice & SST
- RTOFS
- HWRF-GFDL (hurricanes)

Real Time Ocean Forecasting Systems

- **Wave Modeling:**
 - NOAA Wavewatch III
 - Unified model approach
 - Global, regional and hurricane
- **RTOFS Atlantic provides:**
 - Routine estimation of the ocean state [T, S, U, V, W, SSH]
 - Daily 1 week forecast
 - 5 km coastal resolution
 - Initial and boundary conditions for local model applications
- **Global RTOFS uses Navy 1/12 deg. Configuration**
- **Applications:**
 - Downscaling support for water levels (with NOS) for shipping
 - Water quality & Ecosystem and biogeochemical prediction
 - Improved hurricane forecasts
 - Improved estimation of the atmosphere state for global and regional forecasts



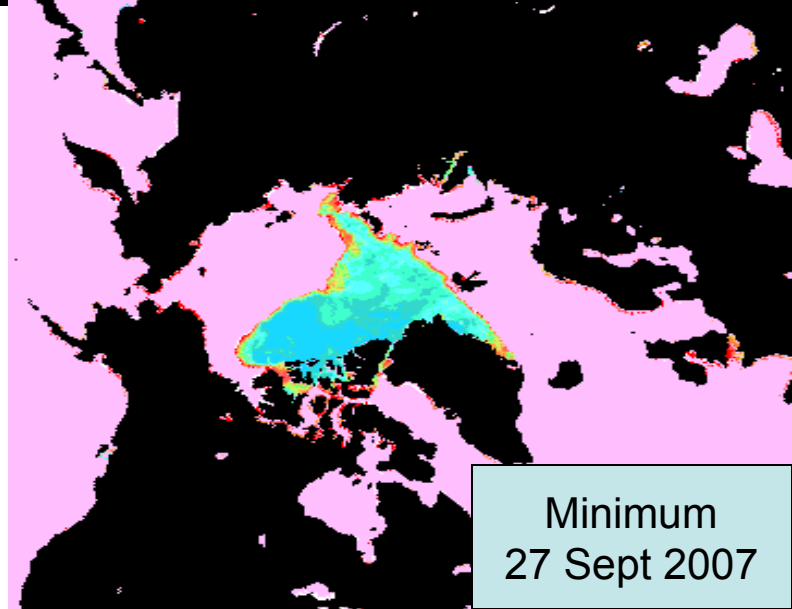
**Marine Products: Sea Ice
Analysis and Forecasts**
Emerging real-time and seasonal
service requirements



R. Grumbine

Sea ice analysis based on
AMSR-E
SSM/I
SSMIS (future)

Dynamic Ice Modeling required for
RTOFS-global
Great Lakes
Climate Forecast System



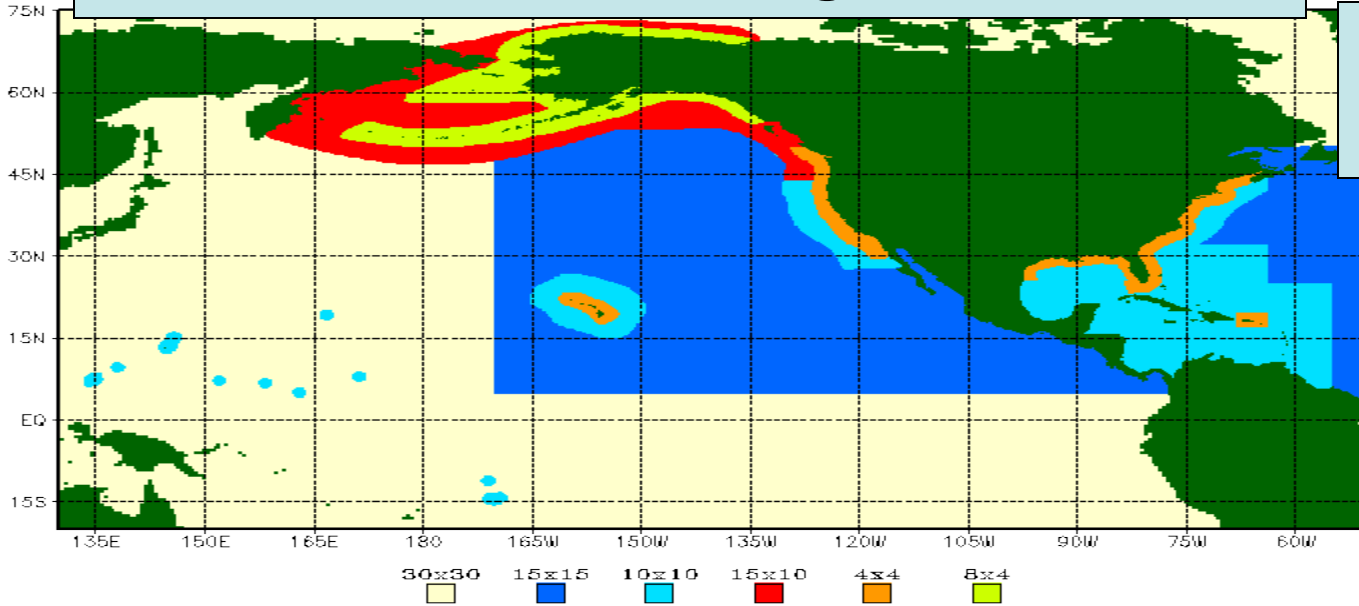
Minimum
27 Sept 2007

Marine Forecast Systems: Wavewatch III

- Developed as NCEP model, but effectively a community modeling framework.
 - Open-source approach (license, trademark).
 - Nearly 500 copies of code distributed.
 - **Many external collaborators / contributors:**
 - **NRL / ONR.**
 - **FNMO**
 - **USACE**
 - **UKMO**
 - **BoM**
 - **7 NOPP teams**
- Operational runs
 - Global mosaic model (30' -4' resolution)
 - Hurricane mosaic model
 - Great Lakes wave models (**NAM or NDFD winds**)
- Assimilation of altimeter and buoy data (**transitioned late FY2011**)
- Multi-model global wave ensemble
 - Joint effort with **FNMO, NAEFS/NUOPC** (Joint product Q4FY2011)
- **Coastal applications**
 - **Relocatable WW III system at NWS Forecast Offices**
 - **Dynamic storm surge (NOS)**

H. Tolman
A. Chawla

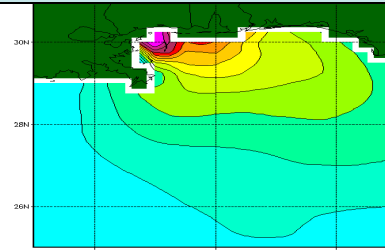
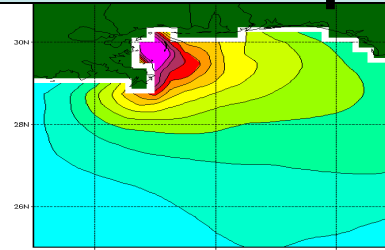
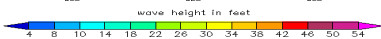
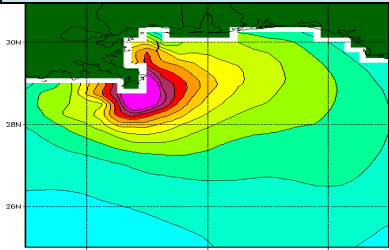
Global wave model grid mosaic



H. Tolman
A. Chawla

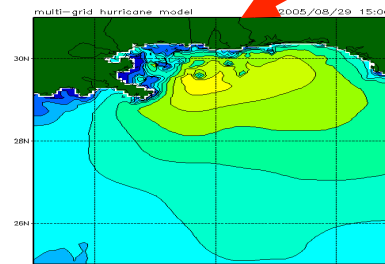
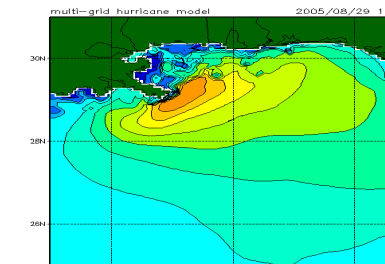
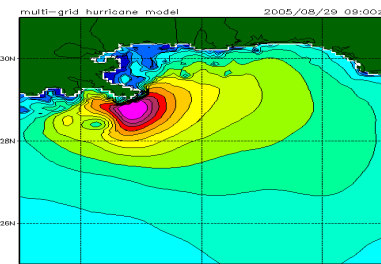
Hurricane application implemented Nov 2010

Former
NAH



Shallow
water
physics

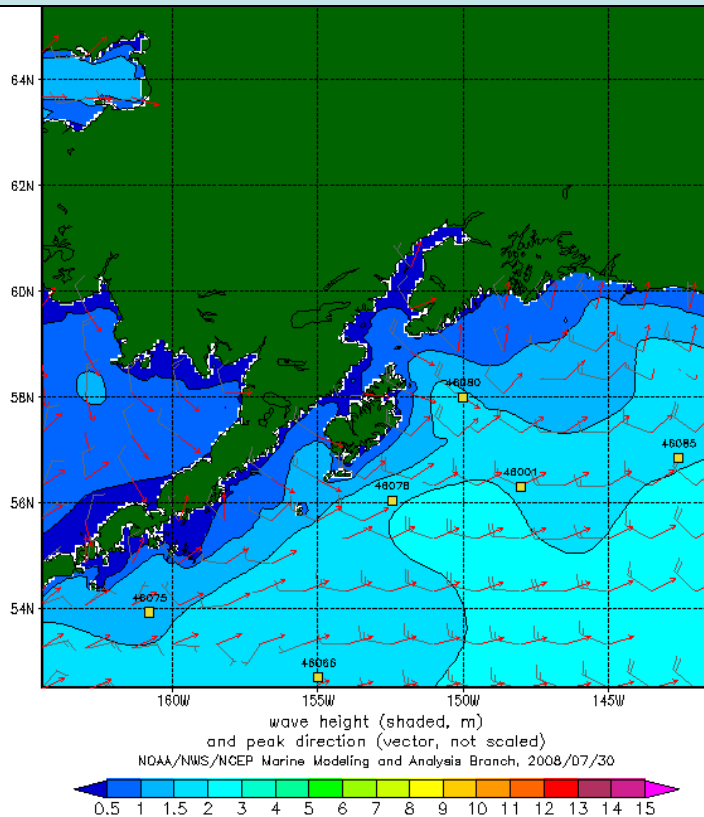
Current
coastal
nested
system



Coastal Wave Applications (cont)

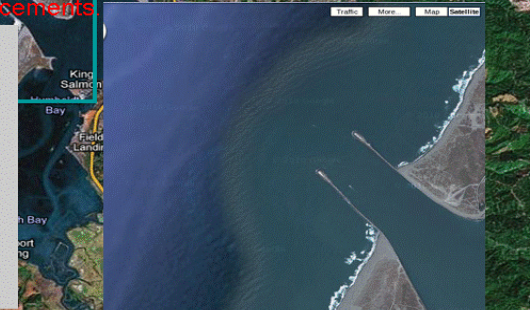
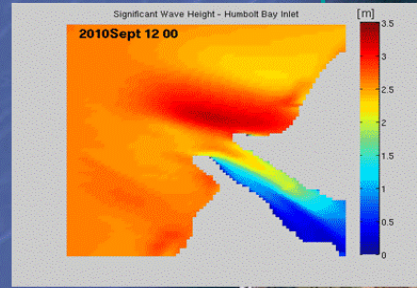
R. Padilla
A. VanderWesthuisen

- Operational global model resolution for Cook Inlet, Alaska
- Future wave reforecast for climate Impacts (forced by CFS Reanalysis)



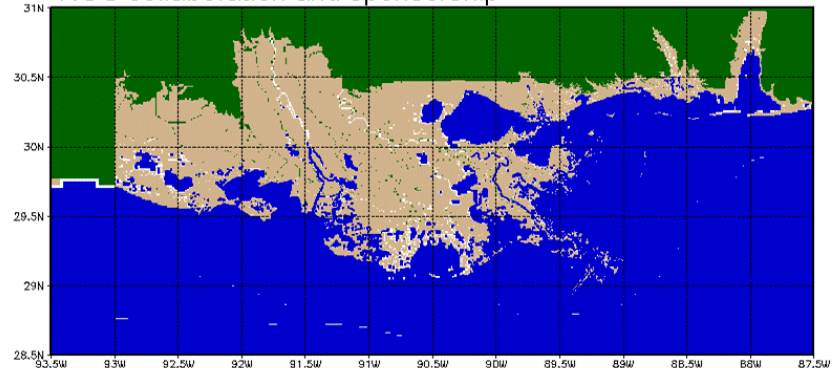
Relocatable Wave Forecast System for Local Applications

- Progress on relocatable wave model:
 - Eureka version of model is running at NCEP
 - Southern Region version is almost running here.
 - Present approach:
 - Modularizing Eureka version
 - Augmenting with SIR enhancements

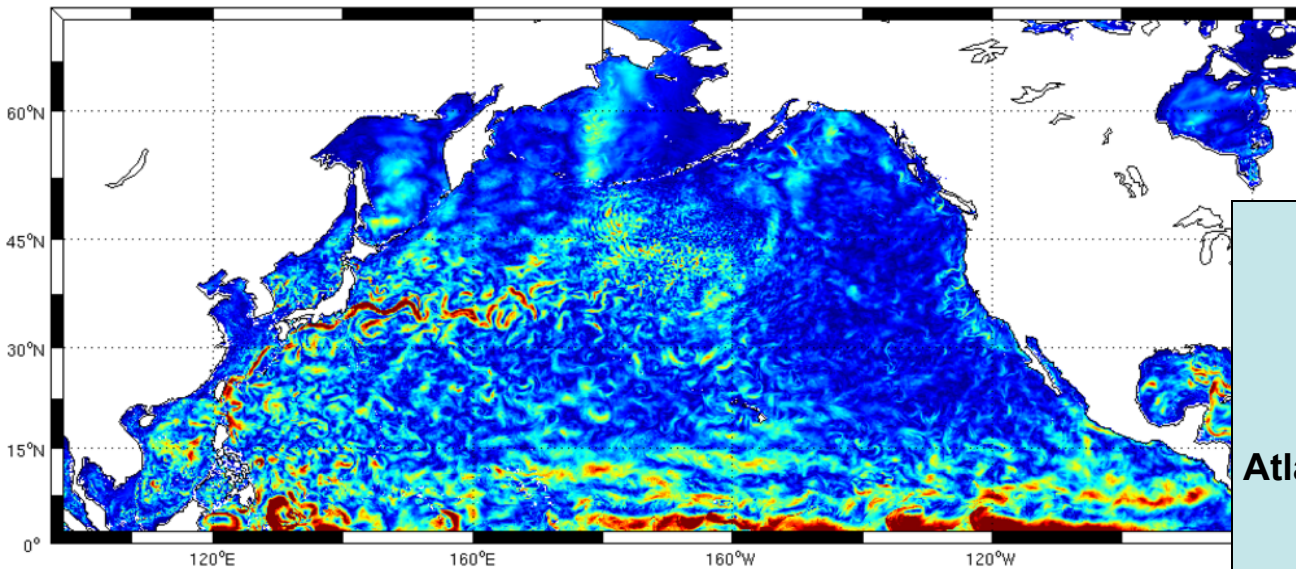


Dynamic Wave Storm-Surge Capability

- Grid resolution up to 400m, working on 100m grids.
- Dynamic inundation using ADCIRC water levels
- Joint project with Northern Gulf Institute through MSU and LSU
- NOS collaboration and sponsorship

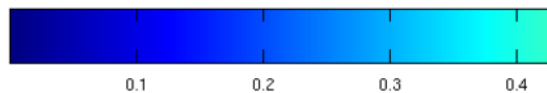


North Pacific Horizontal Current (m/s) 20100819 n00 layer 1
NCEP/EMC/MMAB 20-Aug-2010 max: 3.37 min: 0.00

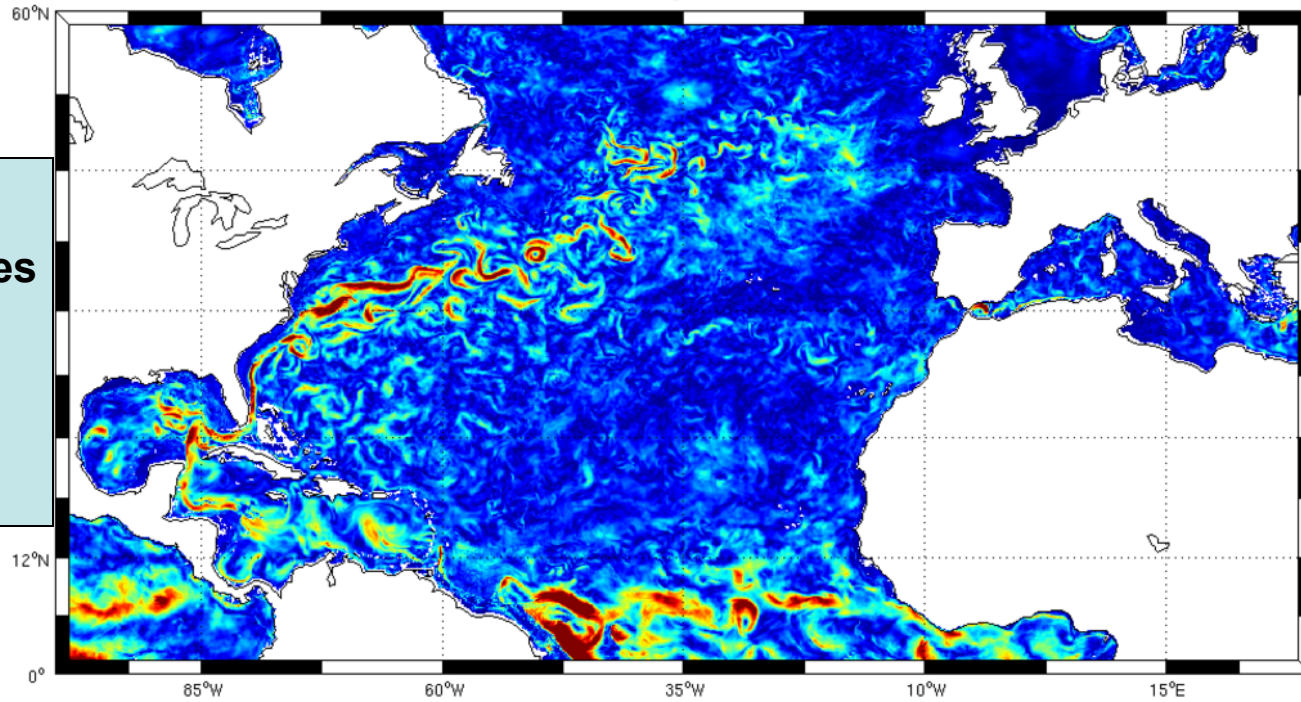


Marine Products: Real Time Ocean Prediction

**Navy global 1/12 degree
configuration**
Surface currents
GFS Forcing
Opnl Q4FY2011
Atlantic basin version for prototyping
Data assimilation in 2014



North Atlantic Horizontal Current (m/s) 20100819 n00 layer 1
NCEP/EMC/MMAB 20-Aug-2010 max: 3.37 min: 0.00



Global support for
Regional (HWRP) hurricanes
Ecosystem downscaling
Wave-current interaction
Global ocean ensemble
(climate application)

Carlos Lozano
Avichal Mehra
MMAB

Overview of the NCEP Hurricane Forecast Systems

- **HWRP**
 - Operational since 2007
 - HWRP atmosphere
 - **WRF 2.0**
 - Movable, two-way 9 km nested vortex following grid
 - 27 km outer domain
 - 42 vertical layers
 - Physics from GFDL/GFS
 - Vortex initialization with GSI/3DVAR
 - **HWRP Ocean**
 - Coupled to Princeton Ocean Model (POM) in the Atlantic Basin
 - Feature based initialization of loop current and warm/cold core rings, cold wake specification during spin-up phase

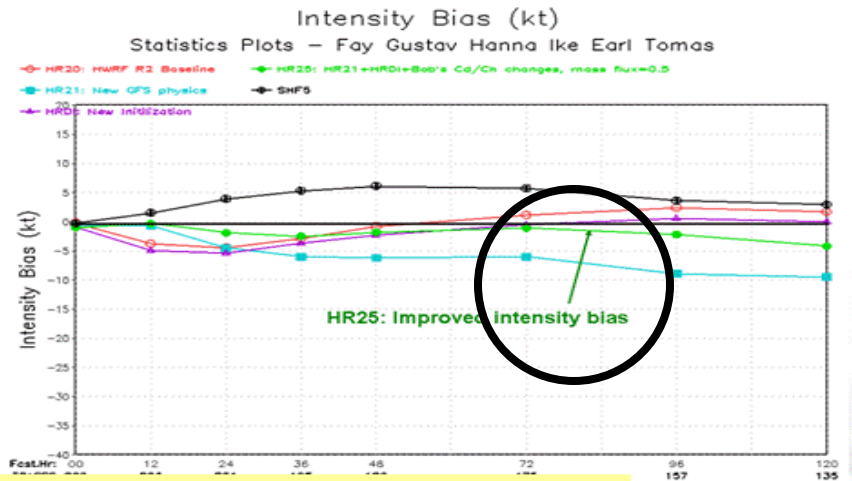
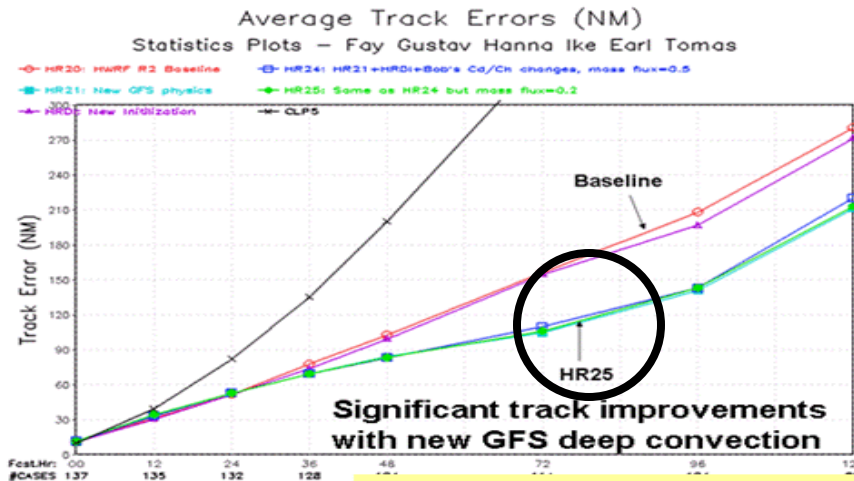
- **GFDL Hurricane Forecast System**
 - Operational since 1995
 - GFDL atmosphere
 - Moveable two-way 9 km nest, vortex following inner nest
 - 27 km outer domain
 - 42 layers
 - GFDL surface layer, GFS convection, microphysics
 - Spin up vortex initialization from axisymmetric model
 - GFDL Ocean
 - Same as HWRP (POM)

V. Tallapragada
Hurricane Team

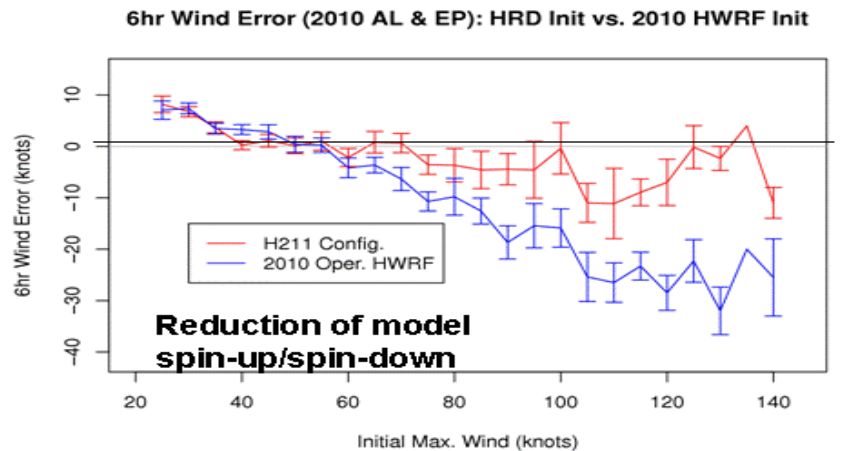
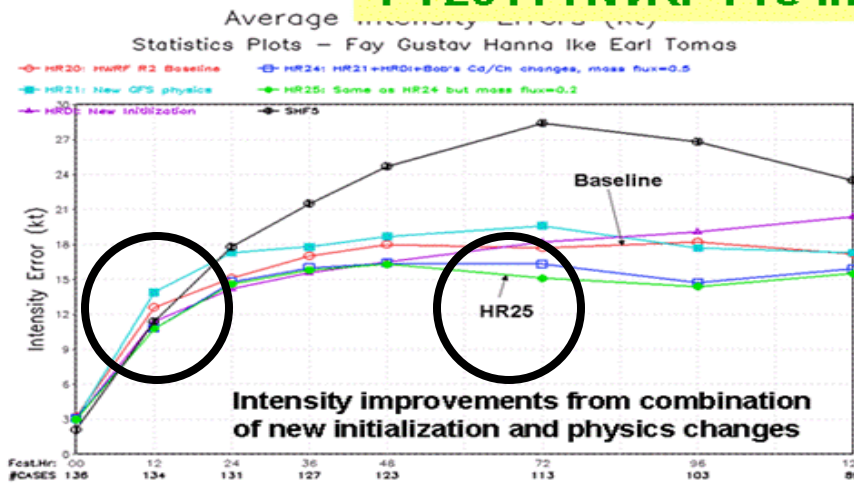
HWRF Testing For 2011 Season

- Potential upgrades are tested for ~700 cases for each configuration
- Final configuration with combined upgrades are chosen in concert with NHC.
- Joint testing of physics/ocean upgrades with GFDL
- Final T&E to be completed by March 15th

V. Tallapragada
Hurricane Team



FY2011 HWRF Pre-Implementation Test Results



Land and Space

- Noah LSM
- ENLIL

N. Amer. Land Data Assimilation System (NLDAS) with Multiple Land Surface Models

- **Multi-model, community-based system**

- Noah (EMC)
- Sacramento (OHD)
- VIC (Princeton U.)
- Catchment (NASA)

- **Forced by observed radiation and precipitation**

- Generates
 - surface fluxes
 - land/soil states
 - runoff & streamflow

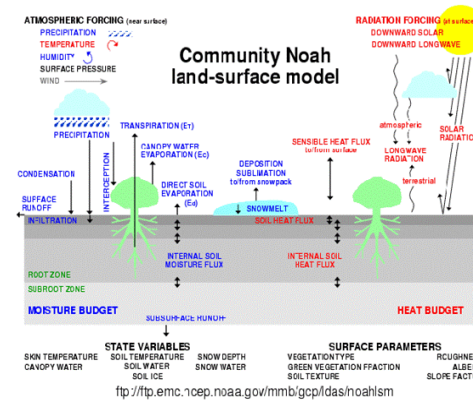
- **30-year land model runs provide climatology**

- **Component of CFS Reanalysis and Reforecast project**

- Anomalies for

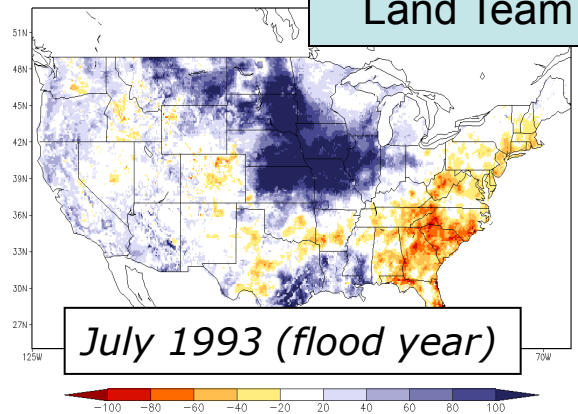
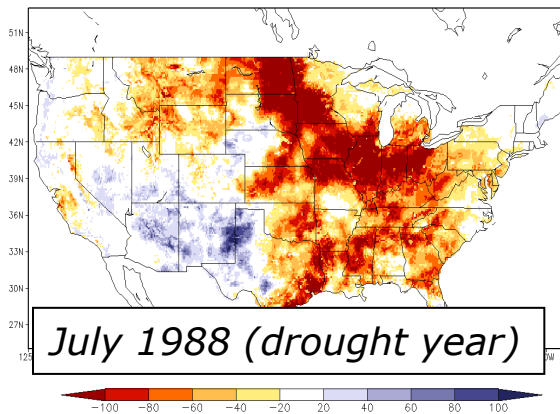
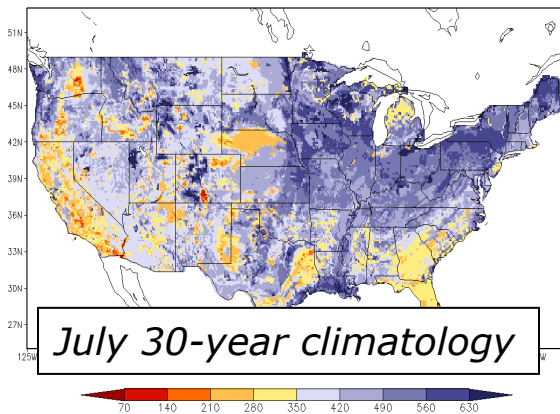
- **Drought monitoring (National Integrated Drought Information System, NIDIS)**
- Seasonal hydrological prediction using climate model downscaled forcing

Noah land-surface model



- Flexible soil layers: default is four soil layers (10, 30, 60, 100 cm thick), be can be specified (2 to N)
- Linearized (non-iterative) surface energy budget; numerically efficient
- Soil hydraulics and parameters follow Cosby et al.
- Canopy resistance follows Jarvis-Stewart "big-leaf"
- Direct soil evaporation
- Canopy interception
- Vegetation-reduced soil thermal conductivity
- Freeze/thaw soil physics
- Snowpack density and water-equivalent content modelled
- Patchy/fractional snow cover effect on surface fluxes; coverage treated as function of snowdepth & veg type
- Flexible vegetation and soil classes and their parameters
- Satellite-based annual cycle of vegetation greenness globally: 5-year monthly climatology (NESDIS AVHRR NDVI-based)

Mike Ek
Land Team

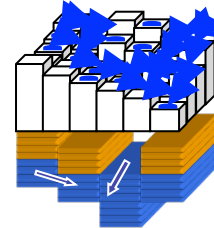


NLDAS four-model ensemble soil moisture monthly anomaly

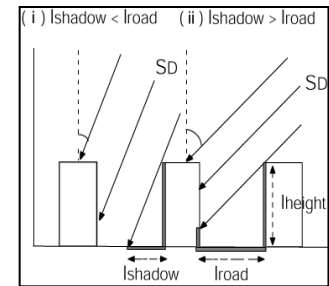
Increasing Requirements on Land Models and system development

- **Hydrology**
 - soil moisture & ground water/water tables
 - irrigation and groundwater extraction
 - water quality
 - streamflow and river discharge to oceans
 - flood/drought
 - Lakes
 - reservoirs management, etc),
- **Biogeochemical cycles**
 - application to terrestrial & marine ecosystems
 - dynamic vegetation and biomass
 - carbon budgets
- **Air Quality and chemistry**
 - interaction with boundary-layer
 - biogenic emissions, VOC
 - dust/aerosols
- **Urban meteorology and surface transportation (land)**
- **Must close budgets (improved physics)**
 - energy
 - water budget
 - biogeochemical cycles
 - air quality

Surface flow



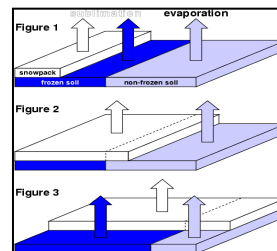
Saturated subsurface flow



Urban-canopy model

**Next Noah Land Model Upgrades
(with community partners:
NASA, NCAR, U. Texas, U. Arizona,
Princeton U, U. Washington, OHD, NESDIS)**

- **Surface/subsurface flow**
- **Groundwater/water table**
- **Land-use/land cover changes (e.g. urban canopy) and urban canopy model**
- **Dynamic (growing) vegetation (2-layer canopy) with CO2 based photosynthesis**
- **Refined evapotranspiration**
- **Surface layer turbulence formulations**
- **Multi-layer snowpack and refined frozen soil processes**



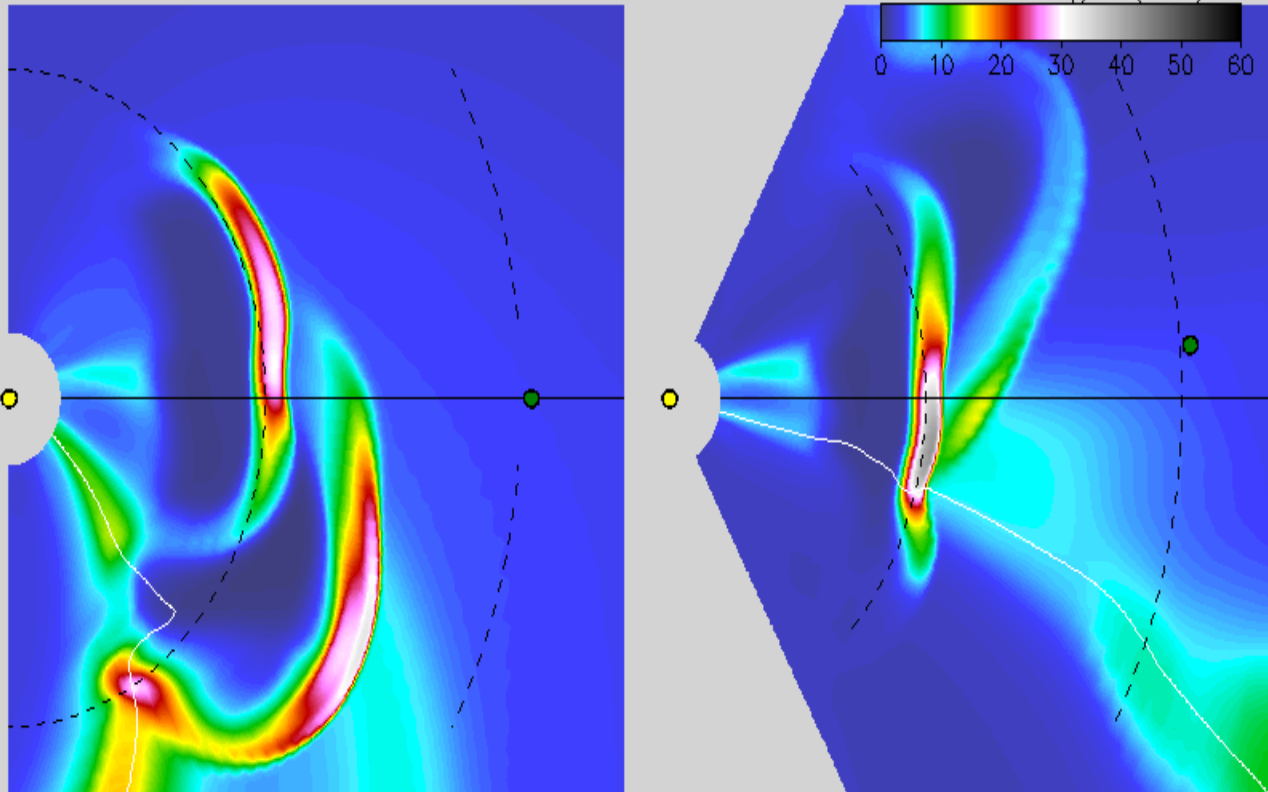
Snowpack & frozen soil

**NASA Land Information System
(LIS) operate in NEMS**

WSA-Enlil : Forecast of multiple CME event : 08/01/2010

2010-08-03 00:00:00

ENLIL-2.6b medres-WSA_V2.2 GONG-2099_102



T. Bogdan
V. Pizzo
SWPC

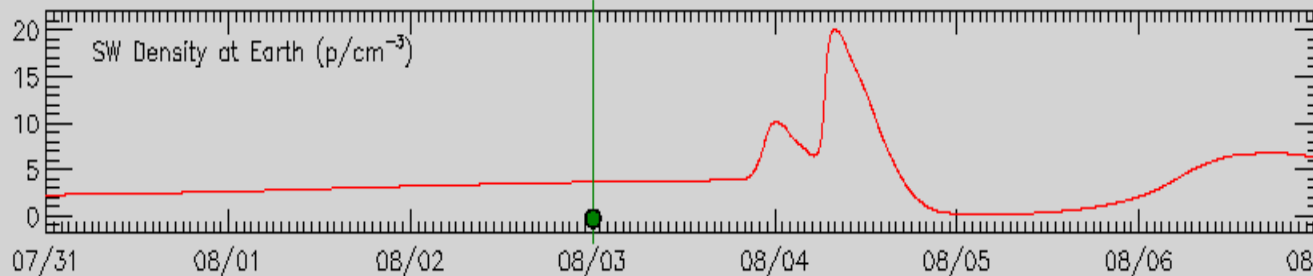


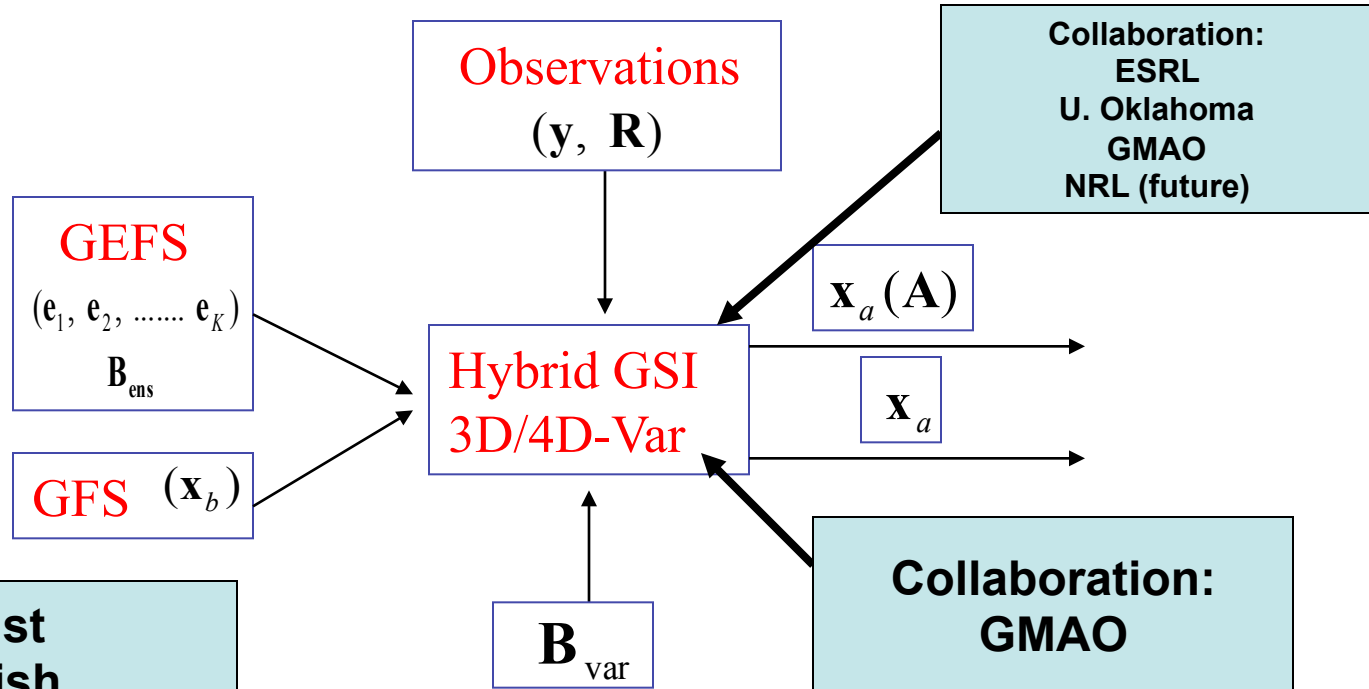
image created: Wed Sep 22 19:10 UTC 2010

First NCEP operational Space Wx system: Q4 FY11 Initial Capability

A Few Development Challenges



NCEP Hybrid Data Assimilation and Ensemble Forecast System

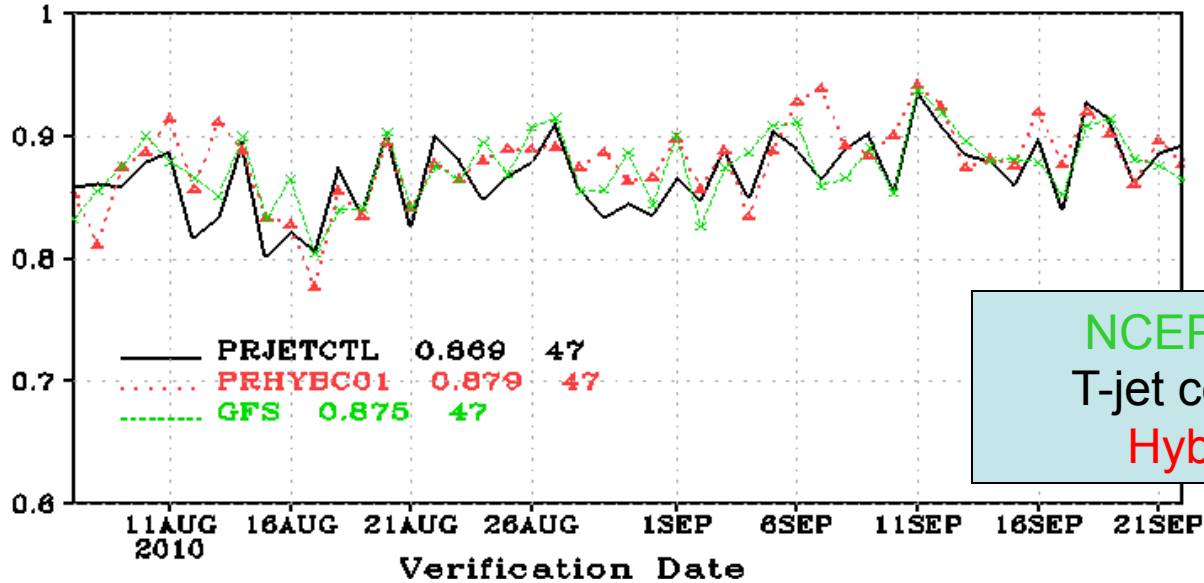


D. Kleist
D. Parrish
J. Derber
Data Assimilation Team

Goal: to develop an efficient NCEP hybrid data assimilation and ensemble generation systems to improve analysis and ensemble forecast performance

500 hPa NH AC Time Series (day 5/6)

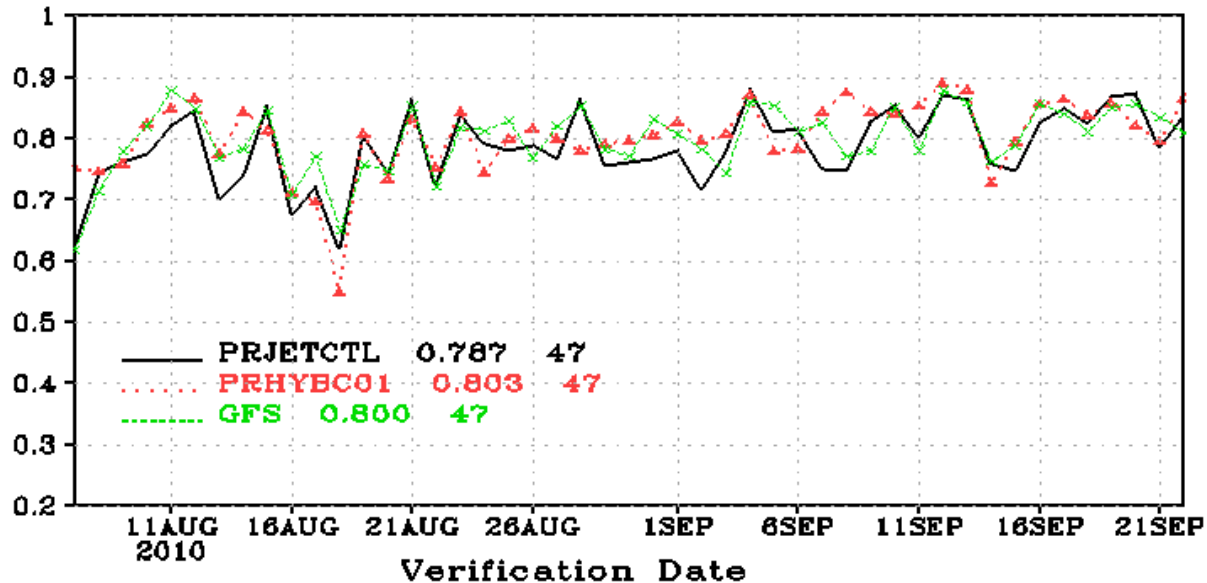
Anomaly Correl: HGT P500 G2/NHX 00Z, Day 5



~1%
NH 5 day AC
improvement

NCEP ops
T-jet control
Hybrid

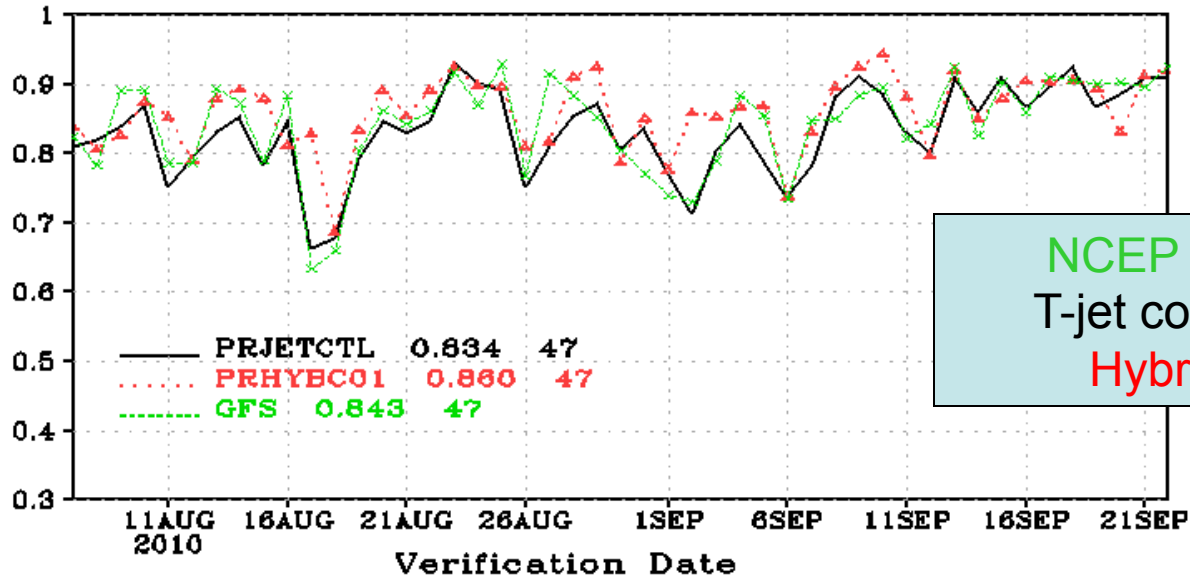
Anomaly Correl: HGT P500 G2/NHX 00Z, Day 6



Kleist
Parrish
& Derber

500 hPa SH AC Time Series (day 5/6)

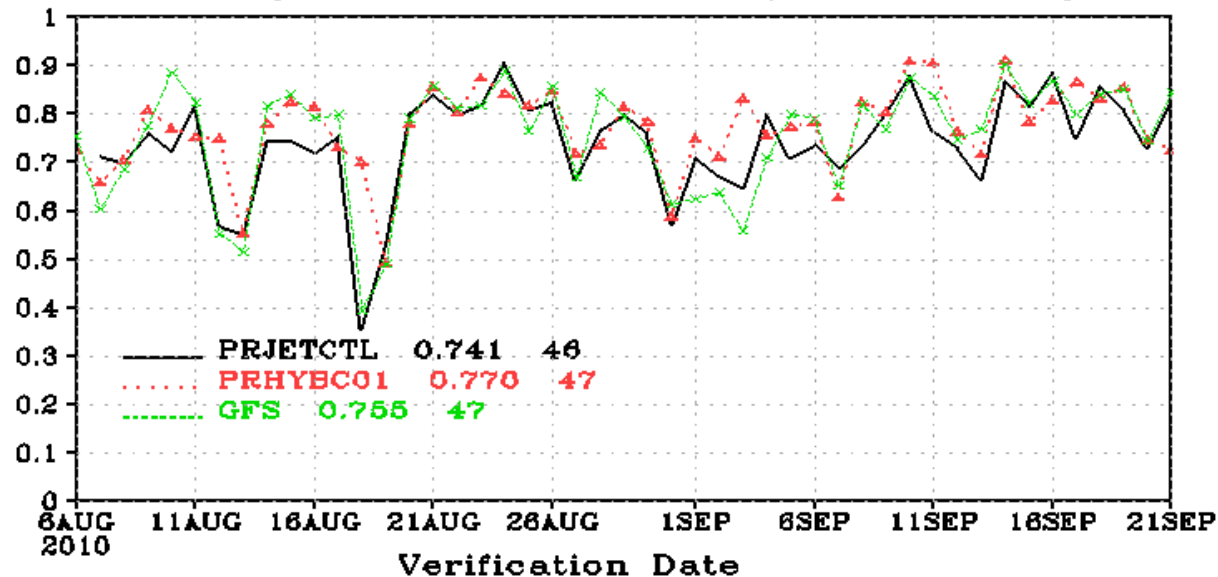
Anomaly Correl: HGT P500 G2/SHX 00Z, Day 5



~2.5%
SH 5 day AC
improvement

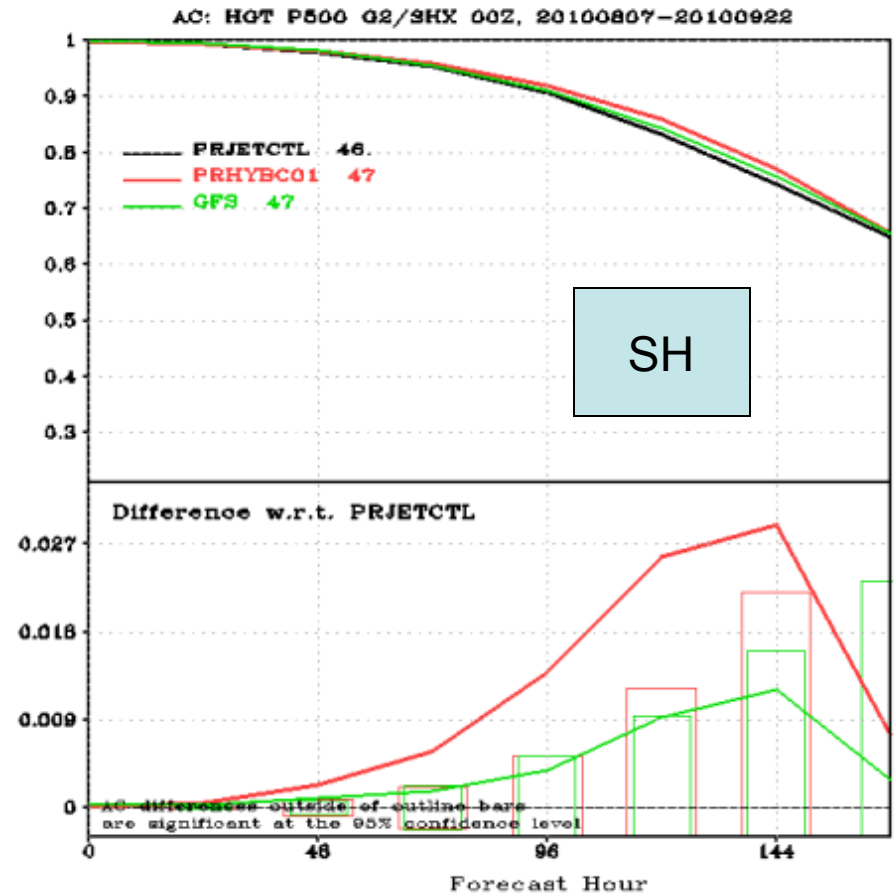
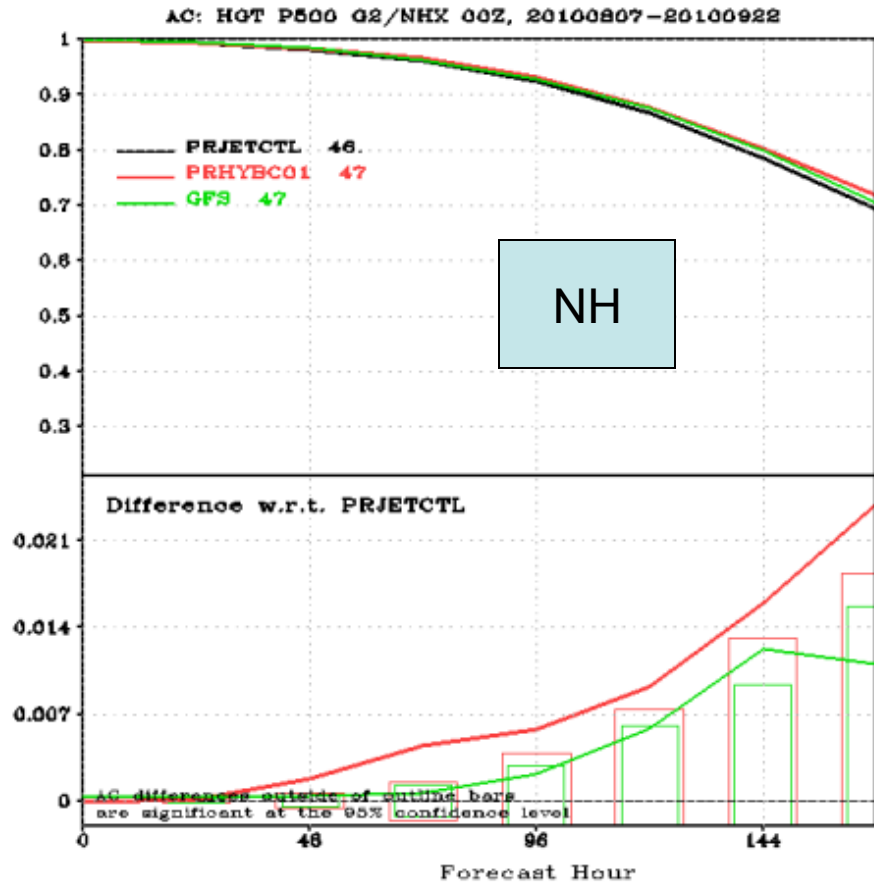
NCEP ops
T-jet control
Hybrid

Anomaly Correl: HGT P500 G2/SHX 00Z, Day 6

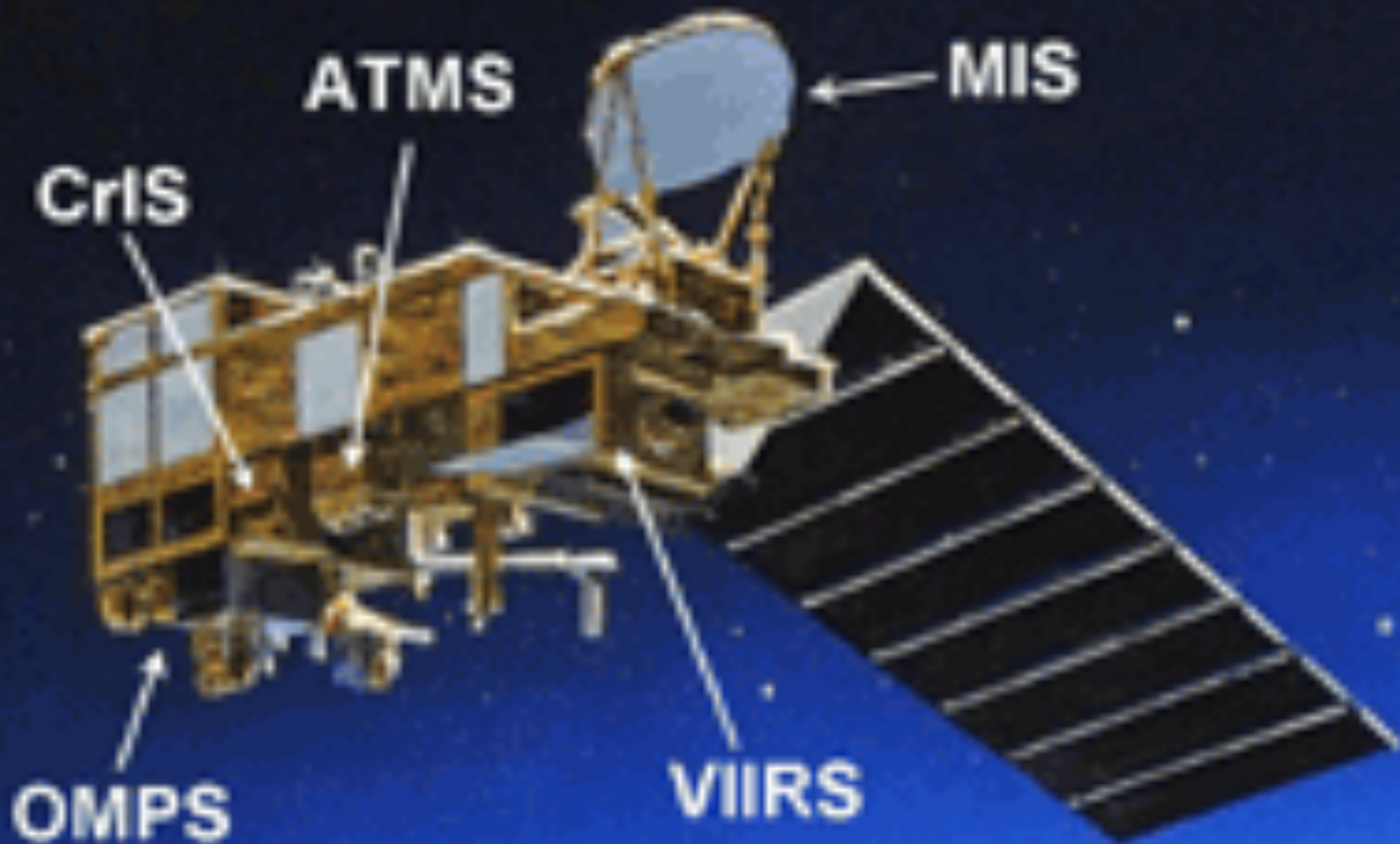


Kleist
Parrish
& Derber

500 hPa Die Off Curves



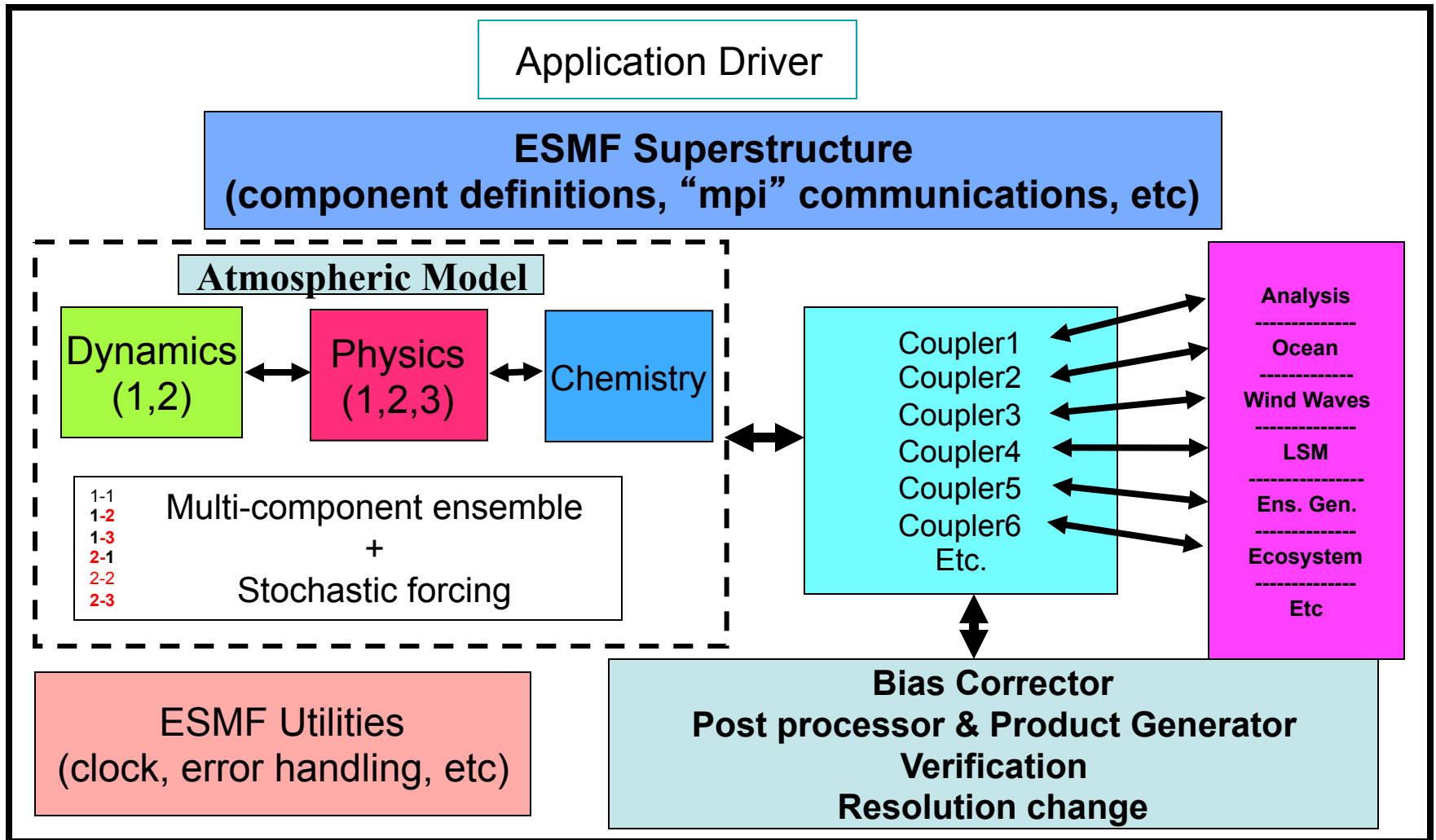
Hybrid improvement over control (beyond 95% confidence). Improvements are substantial in SH.



NPP → JPSS and DoD instruments

NOAA Environmental Modeling System (NEMS)

(uses standard ESMF compliant software)



* Earth System Modeling Framework (NCAR/CISL, NASA/GMAO, Navy (NRL), NCEP/EMC), NOAA/GFDL

2, 3 etc: NCEP supported thru NUOPC, NASA, NCAR or NOAA institutional commitments 59

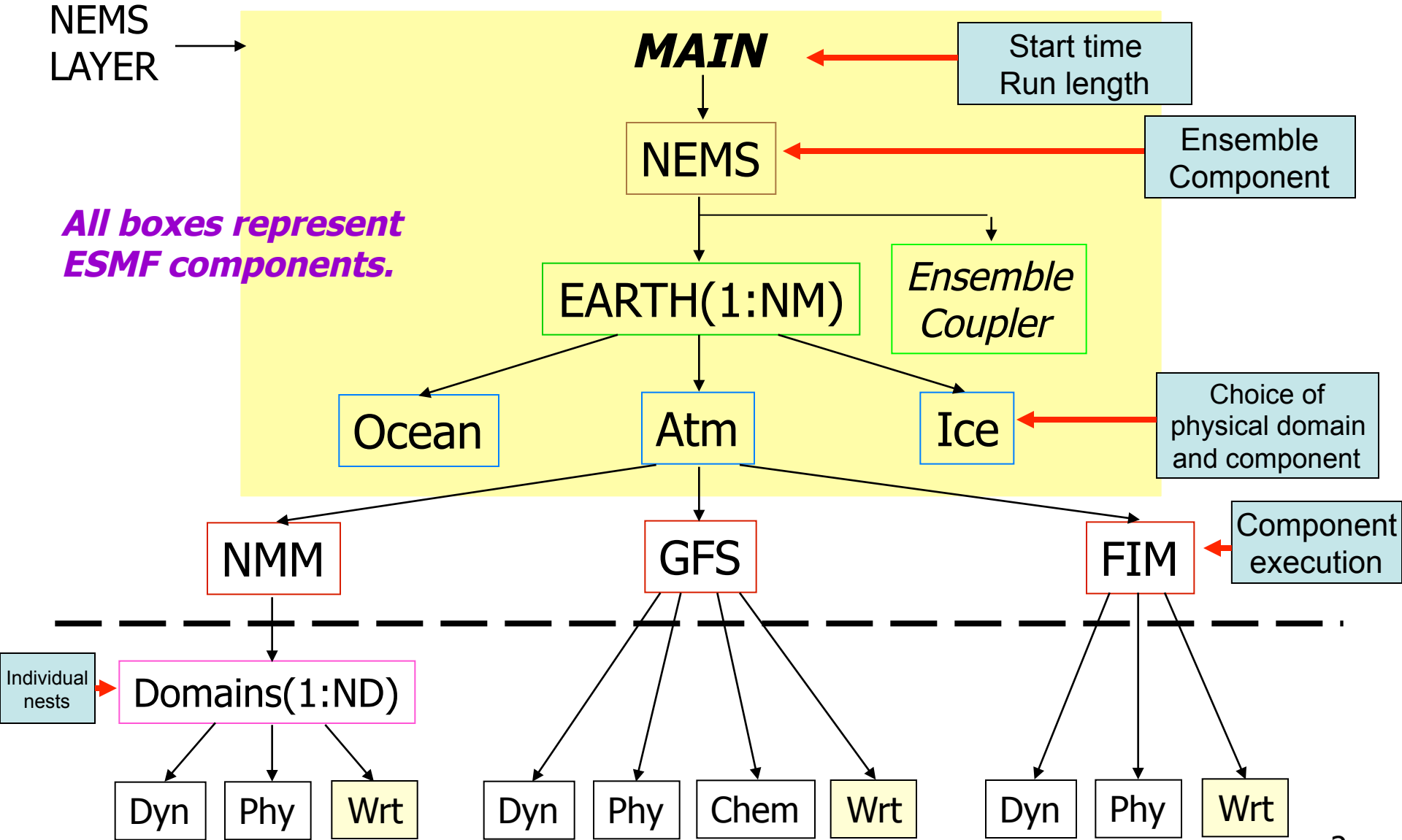
Components are: Dynamics (spectral, FV, NMM, FIM, ARW, COAMPS...)

Physics (GFS, NRL, NCAR, GMAO, ESRL, GFDL...)

NEMS Component Structure

NEMS
LAYER

*All boxes represent
ESMF components.*



Below the dashed line the source codes are organized by the model developers.

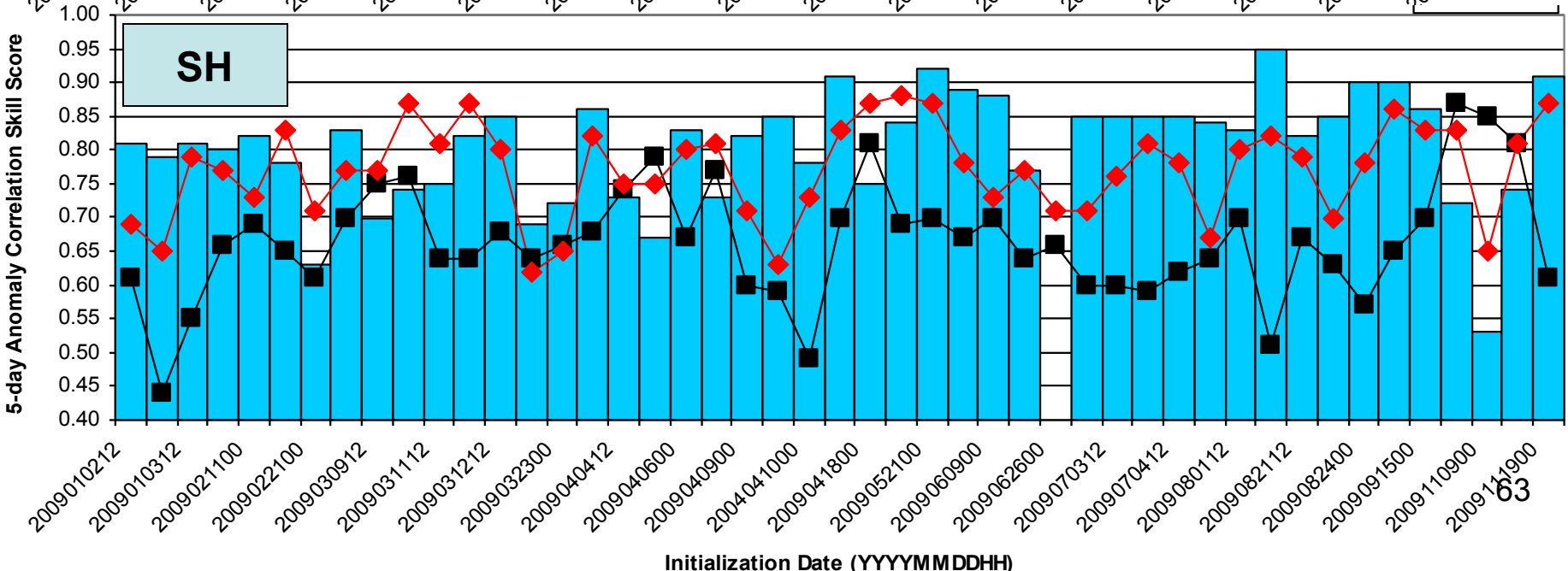
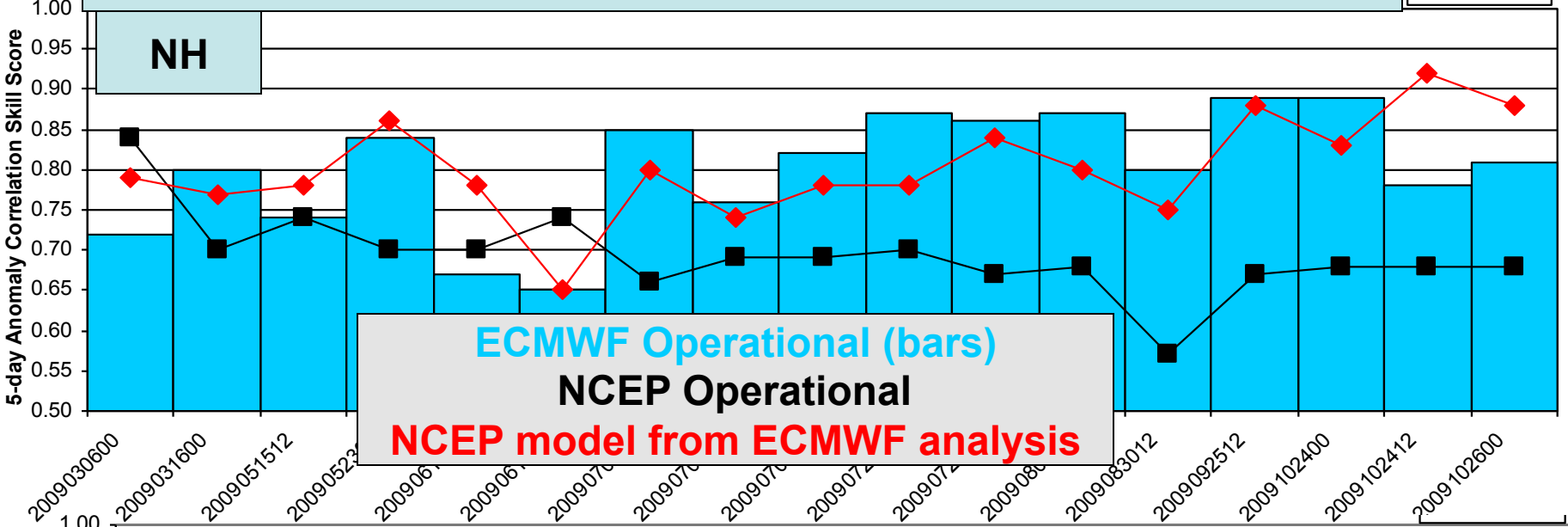
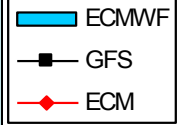
Summary

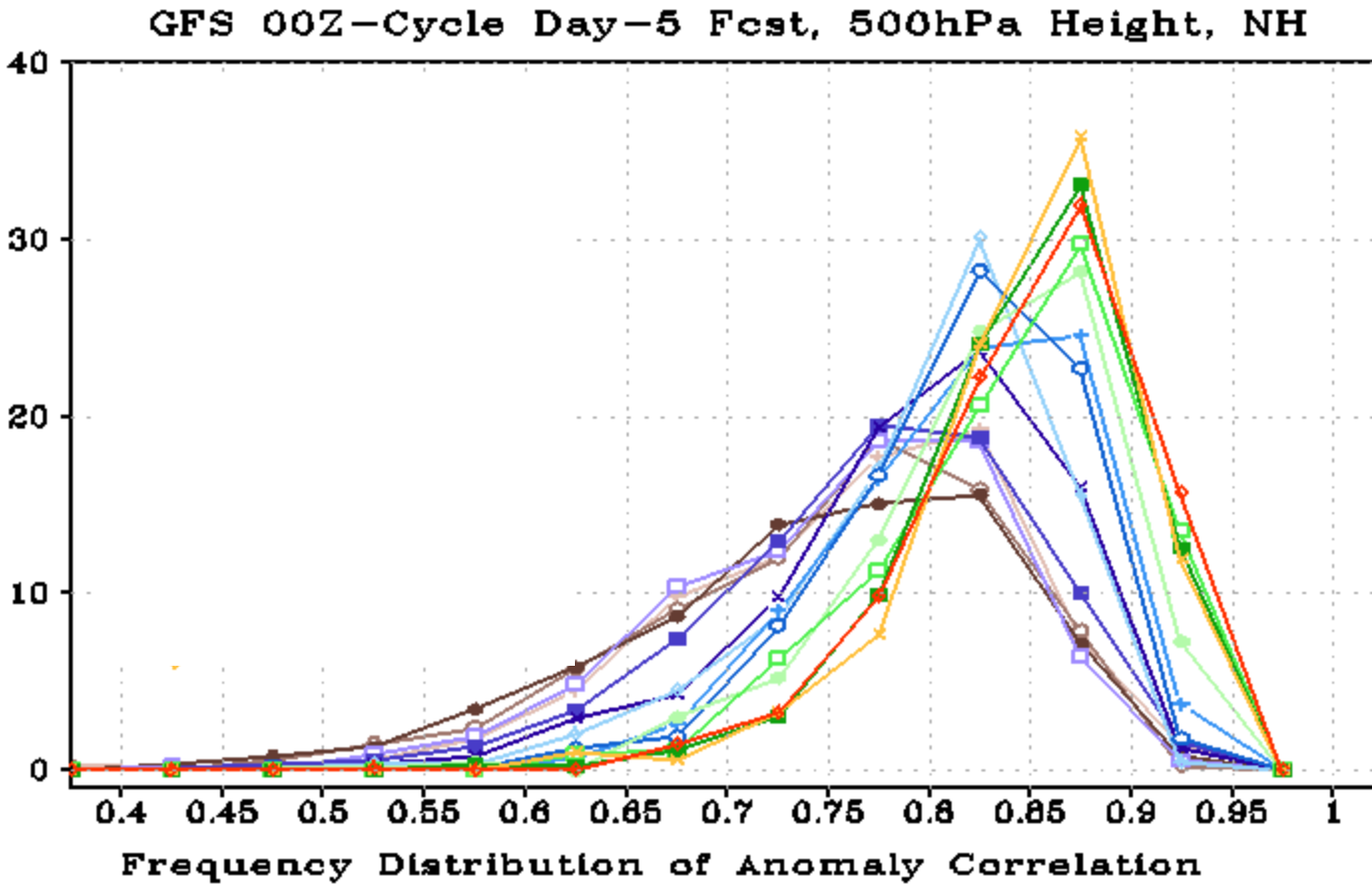
- **NCEP EMC supports mission-oriented numerical forecast guidance for NOAA**
 - Scope is expanding to meet societal needs
 - Plans for supporting technology are established for the next 5 years
- **Many technology upgrades are in progress**
 - With community participation
 - Offer opportunity to dramatically improve guidance in
 - Severe weather
 - Hurricanes
 - Climate
 - Ocean and ecosystems
- **Engineering renovation of NCEP Production Suite is essential for achieving greater efficiency and uniformity across the many application areas**
- **Path to forecast system improvements is unclear and potentially treacherous**
 - Improvements often come through attention to detail rather than the big splash

How To Improve a Forecast System

- Horizontal resolution
- Vertical resolution and domain
- Improve data assimilation
 - e.g. hybrid variational-ensemble, 4d-var
 - Background error formulation
 - Time continuity
 - Quality control
- Add observations
- Upgrade dynamics
 - Improve efficiency
 - New formulation
- Coupling (atmosphere-land-ocean-sea ice-chemistry, ...)
- Upgrade physics and add physical processes
 - Improve convection, PBL, land surface, gravity wave drag, etc.
 - Aerosols and radiative impacts
 - Remove parameterizations (high resolution)
- Tune model
- Diagnostics and applied problem solving
- Other

Sample of NH and SH Poor Forecast Cases



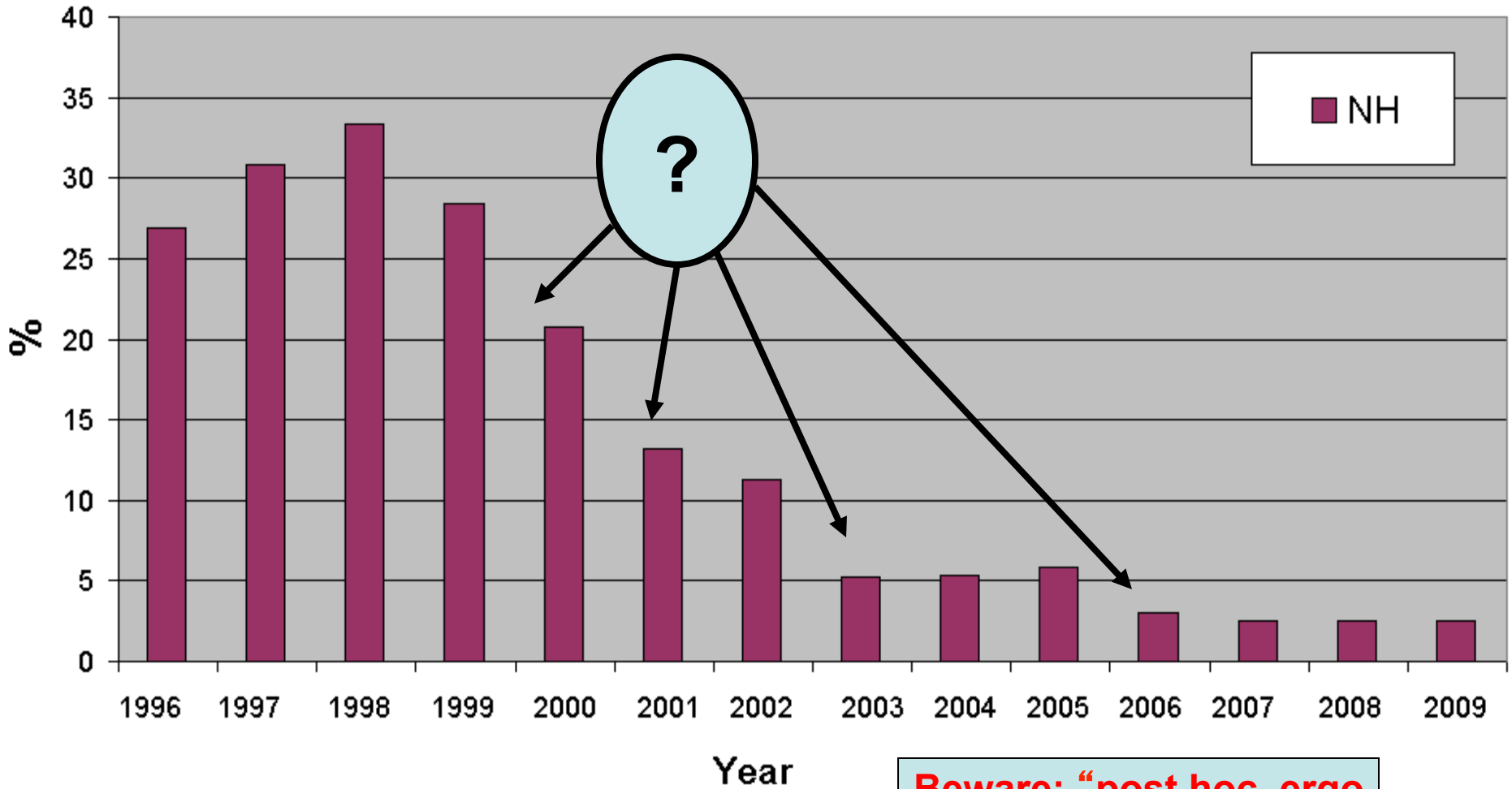


Fanglin Yang

- **Look at the history of extremes in the distribution**
 - Scores < 0.7 (dropout criterion)
 - Excellent forecasts (> 0.9)

Percent of Poor (Busted) Forecasts

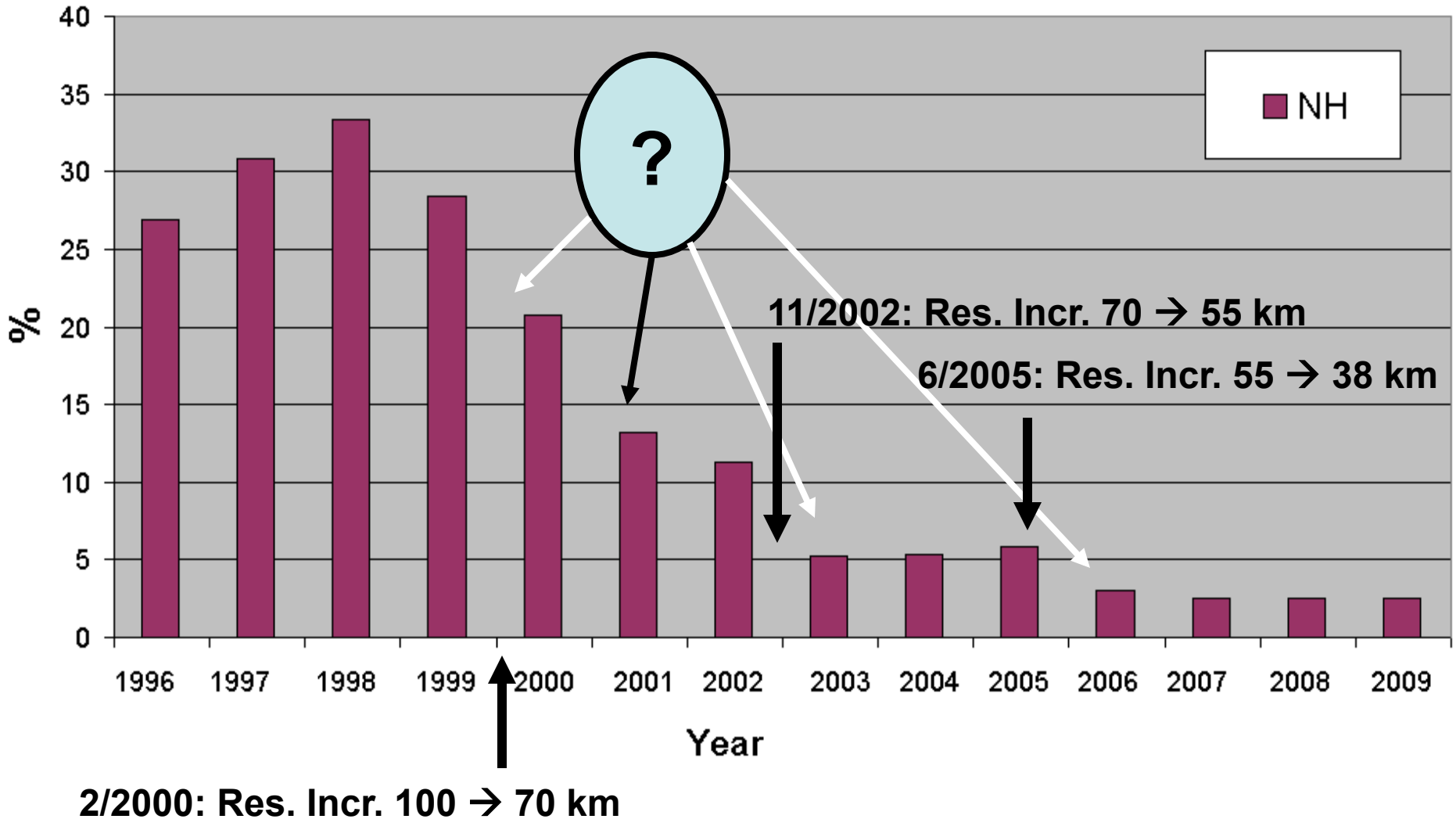
Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



Beware: "post hoc, ergo proper hoc"

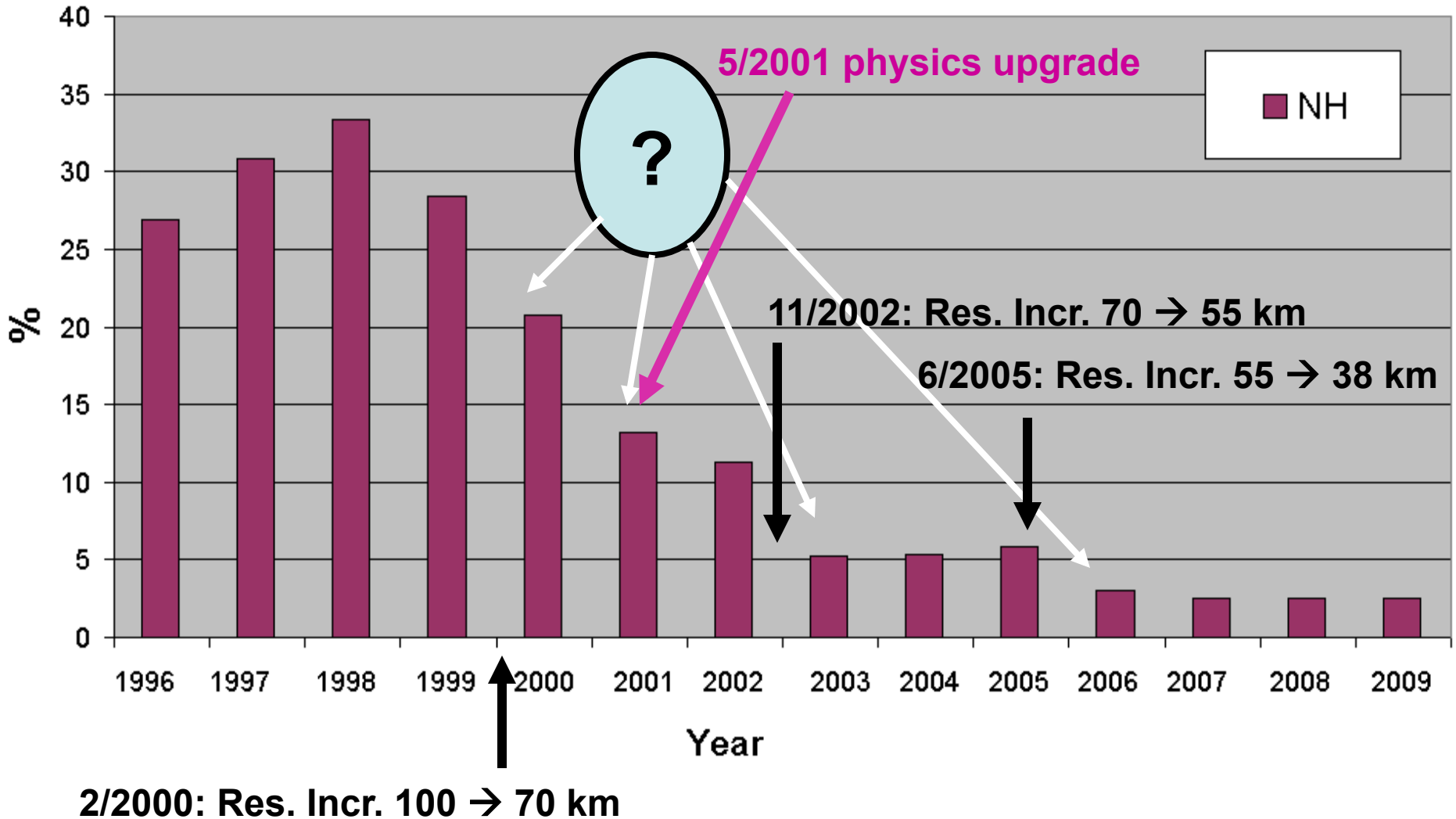
Percent of Poor (Busted) Forecasts

Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



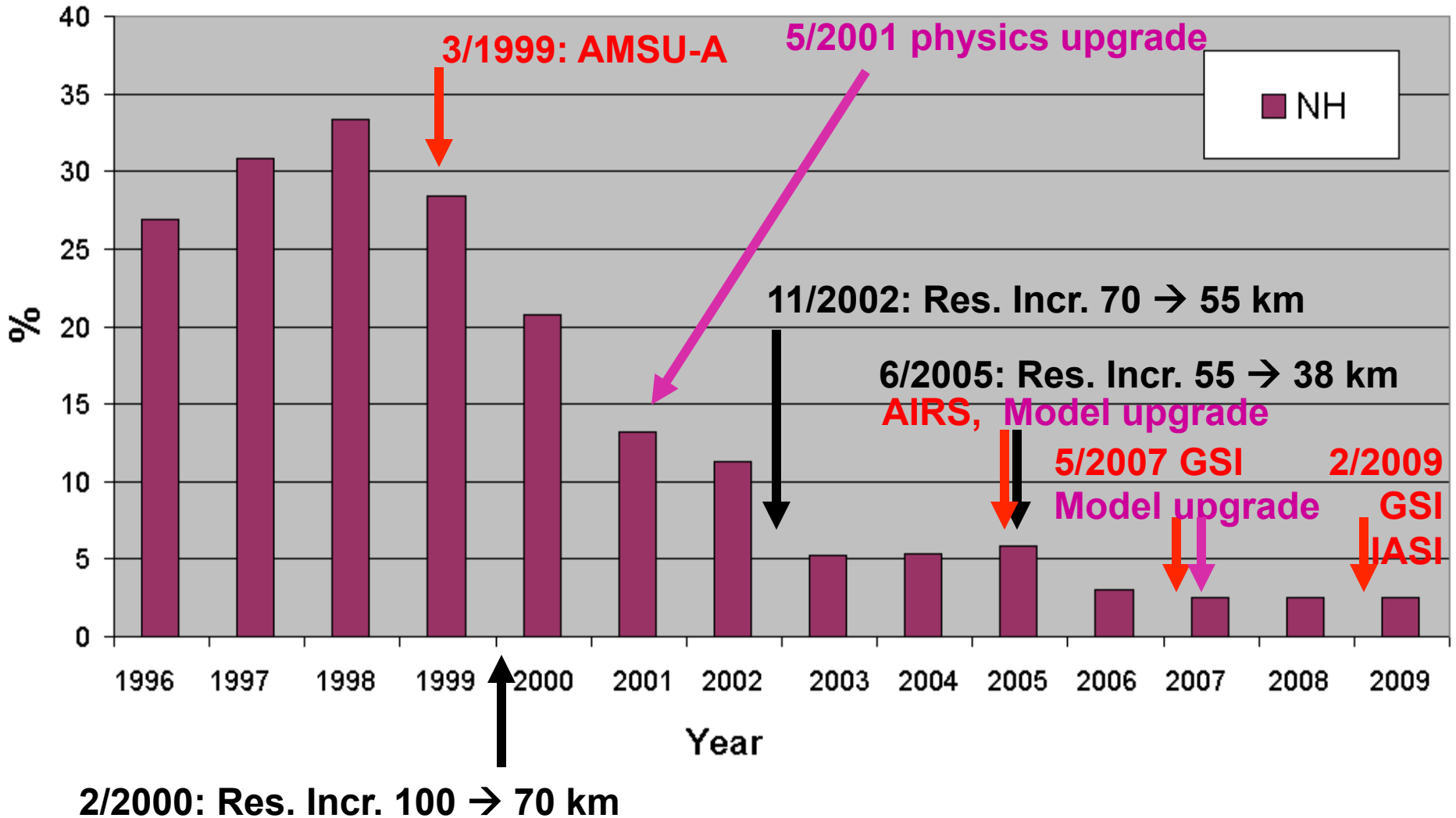
Percent of Poor (Busted) Forecasts

Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



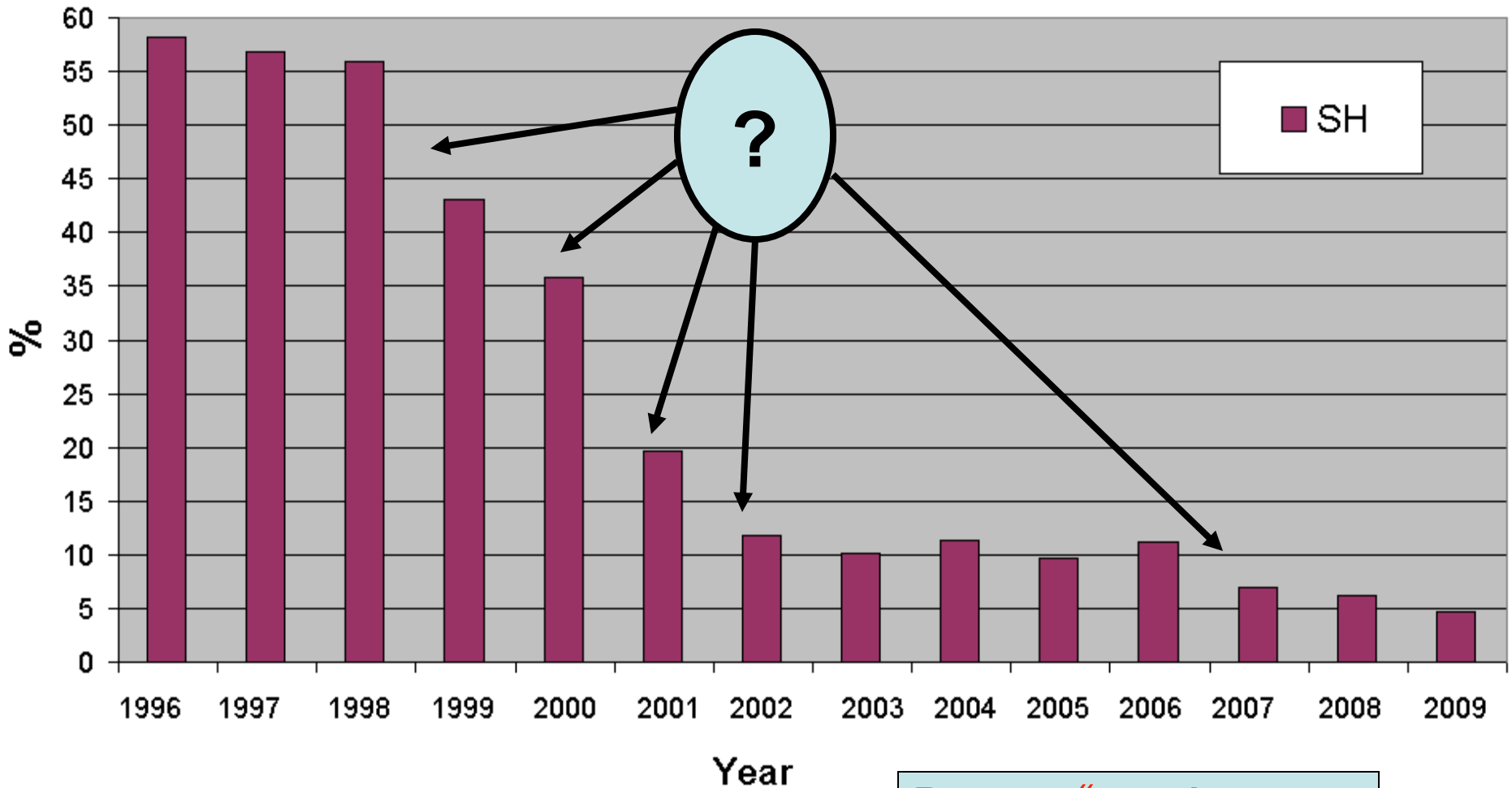
Percent of Poor (Busted) Forecasts

Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



Percent of Poor (Busted) Forecasts

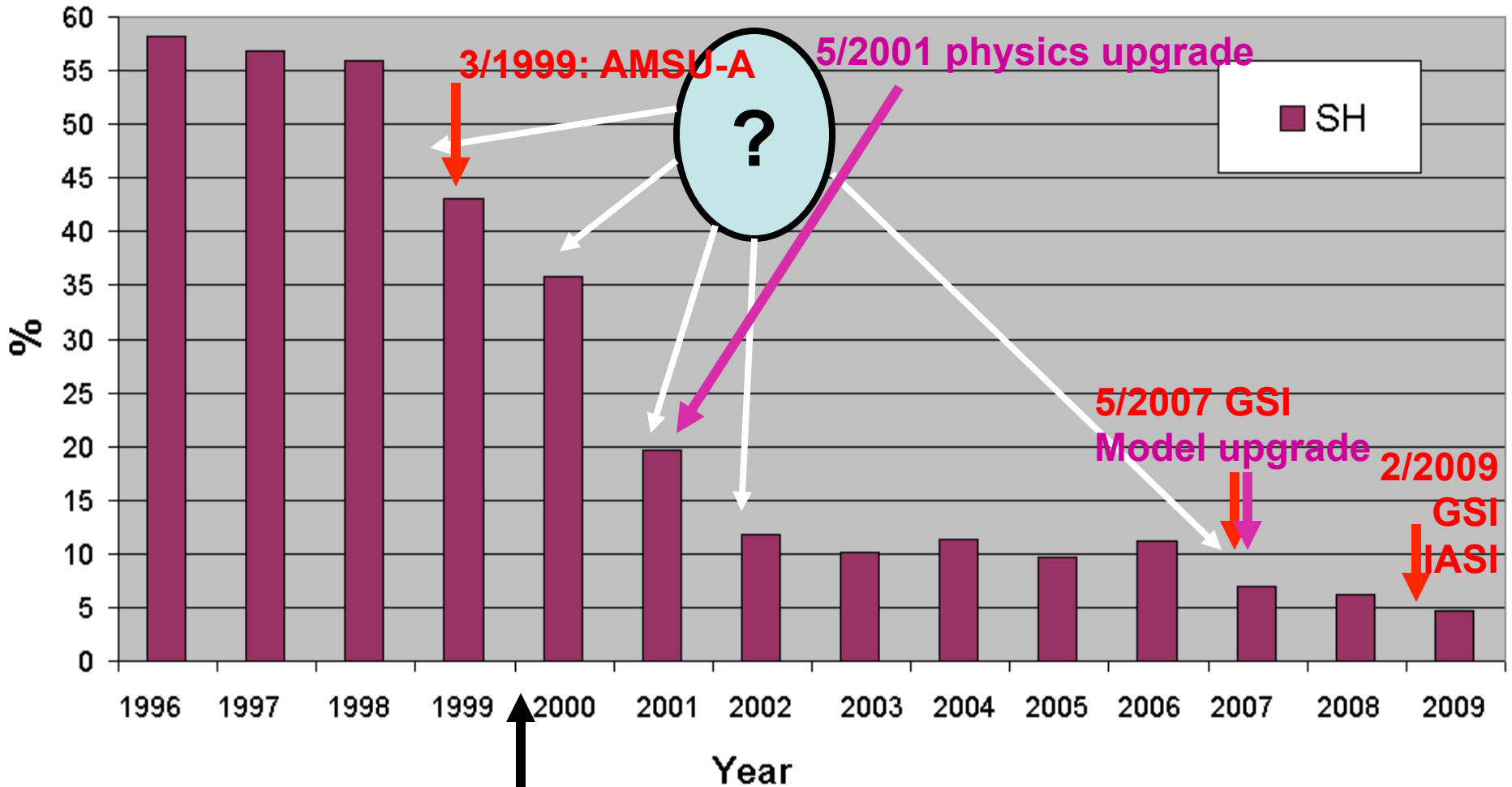
Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



Beware: "post hoc, ergo proper hoc"

Percent of Poor (Busted) Forecasts

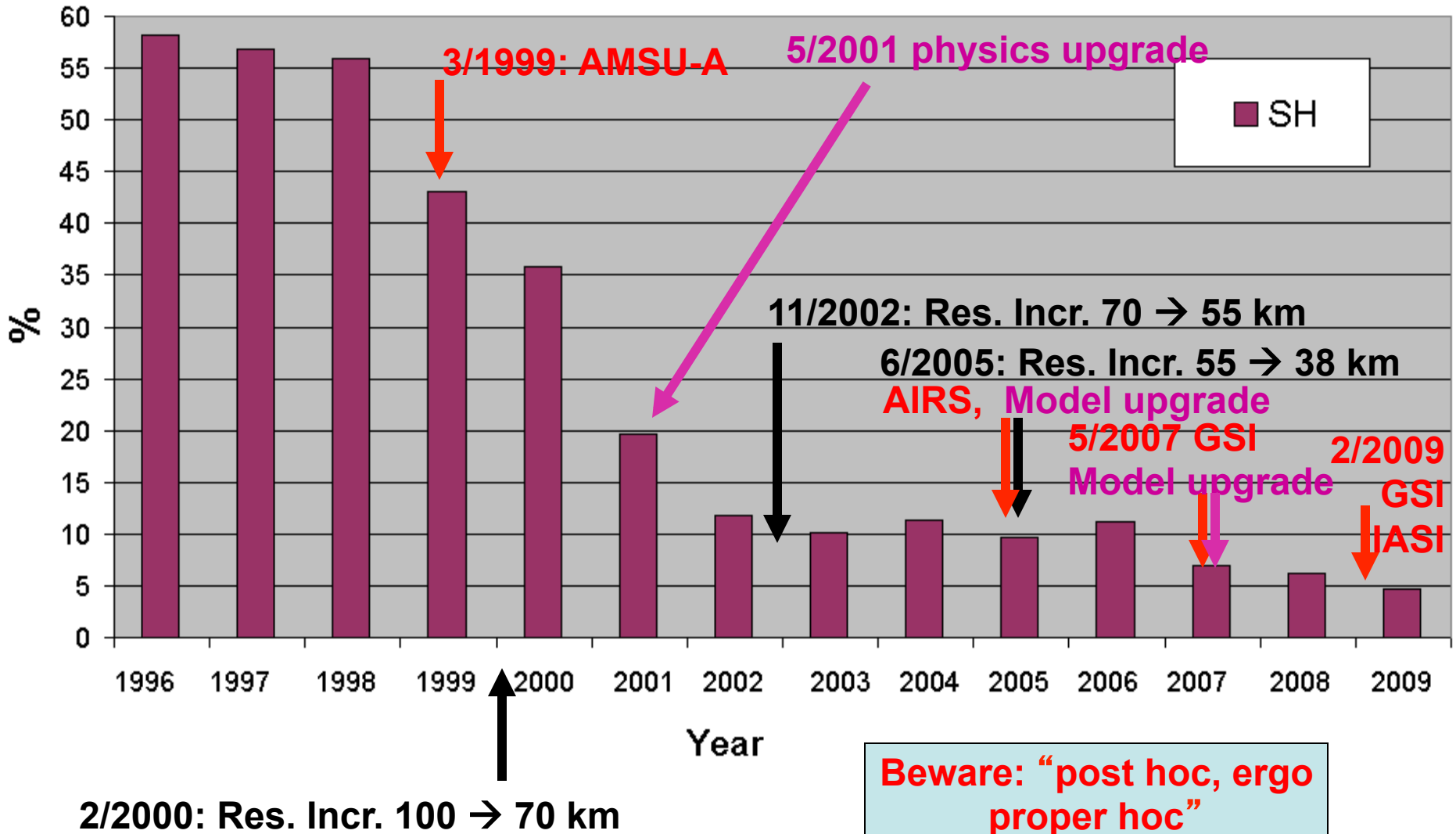
Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



2/2000: Res. Incr. 100 → 70 km

Percent of Poor (Busted) Forecasts

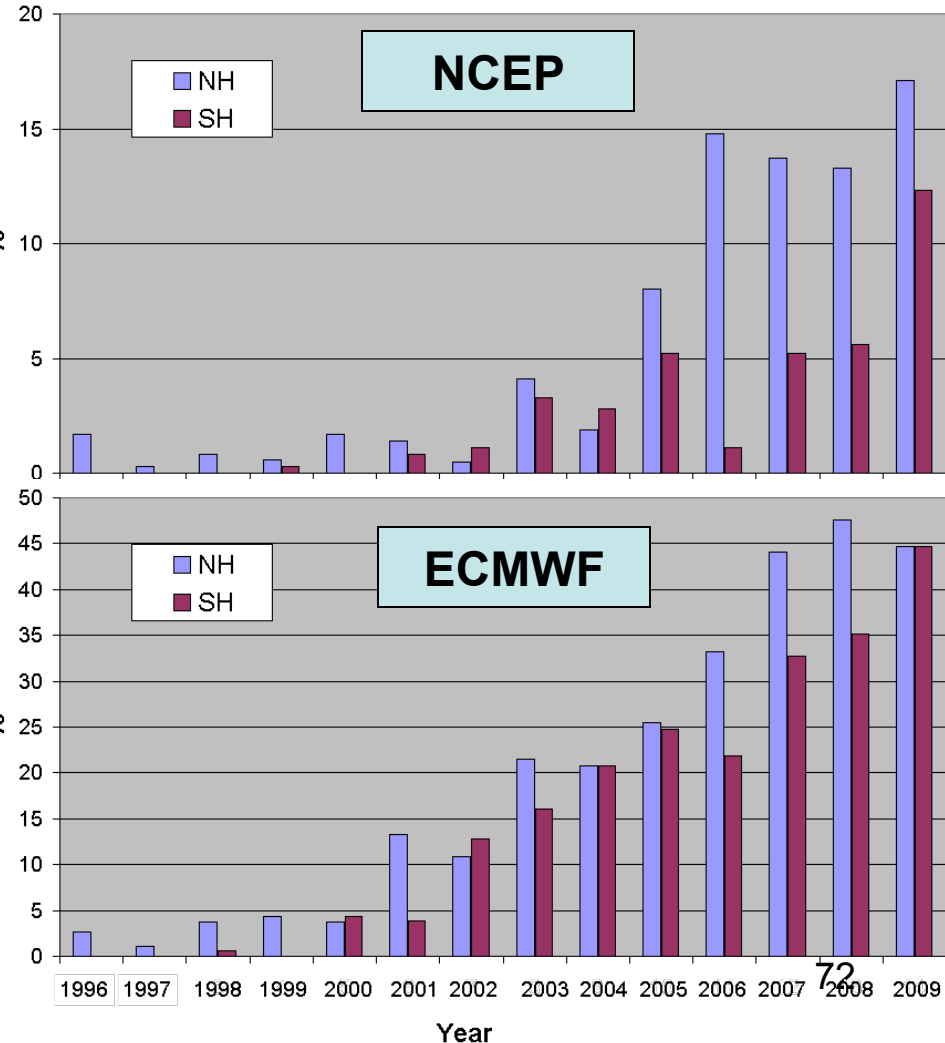
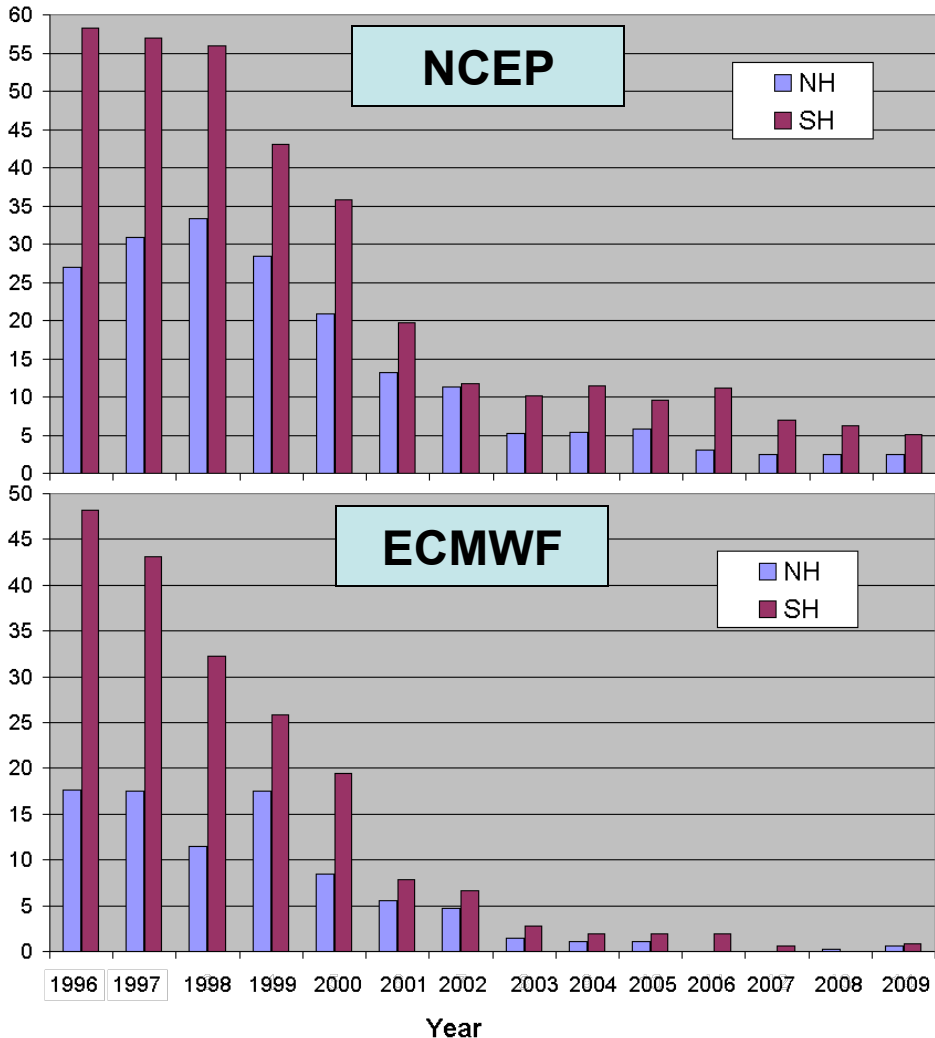
Percent Count of Anomaly Correlations Below 0.7
GFS 00Z-Cycle Day-5 Forecast, 500hPa Height



Does It Make a Difference to How Forecasters Use Product?

Percent Poor Forecasts

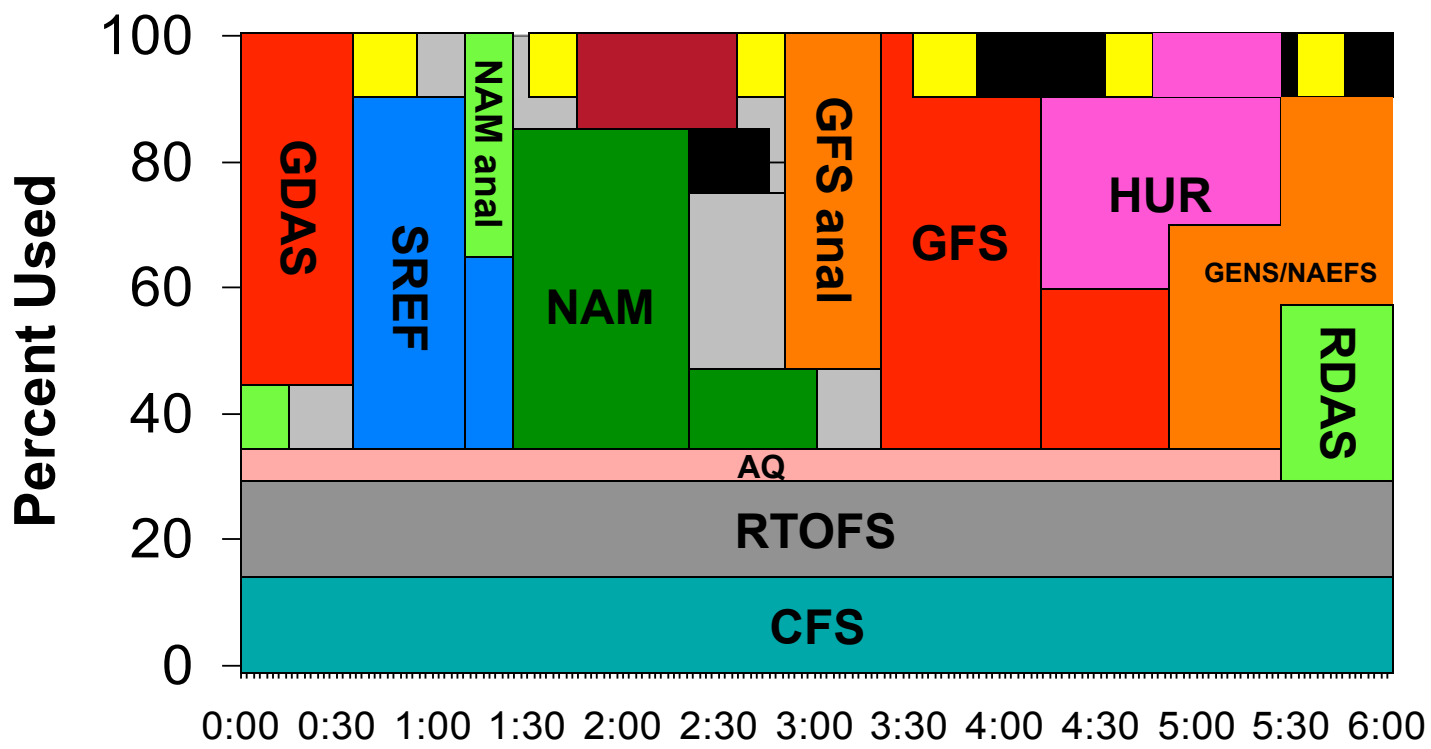
Percent Good Forecasts



NCEP Production Suite Weather, Ocean, Land & Climate Forecast Systems

Current

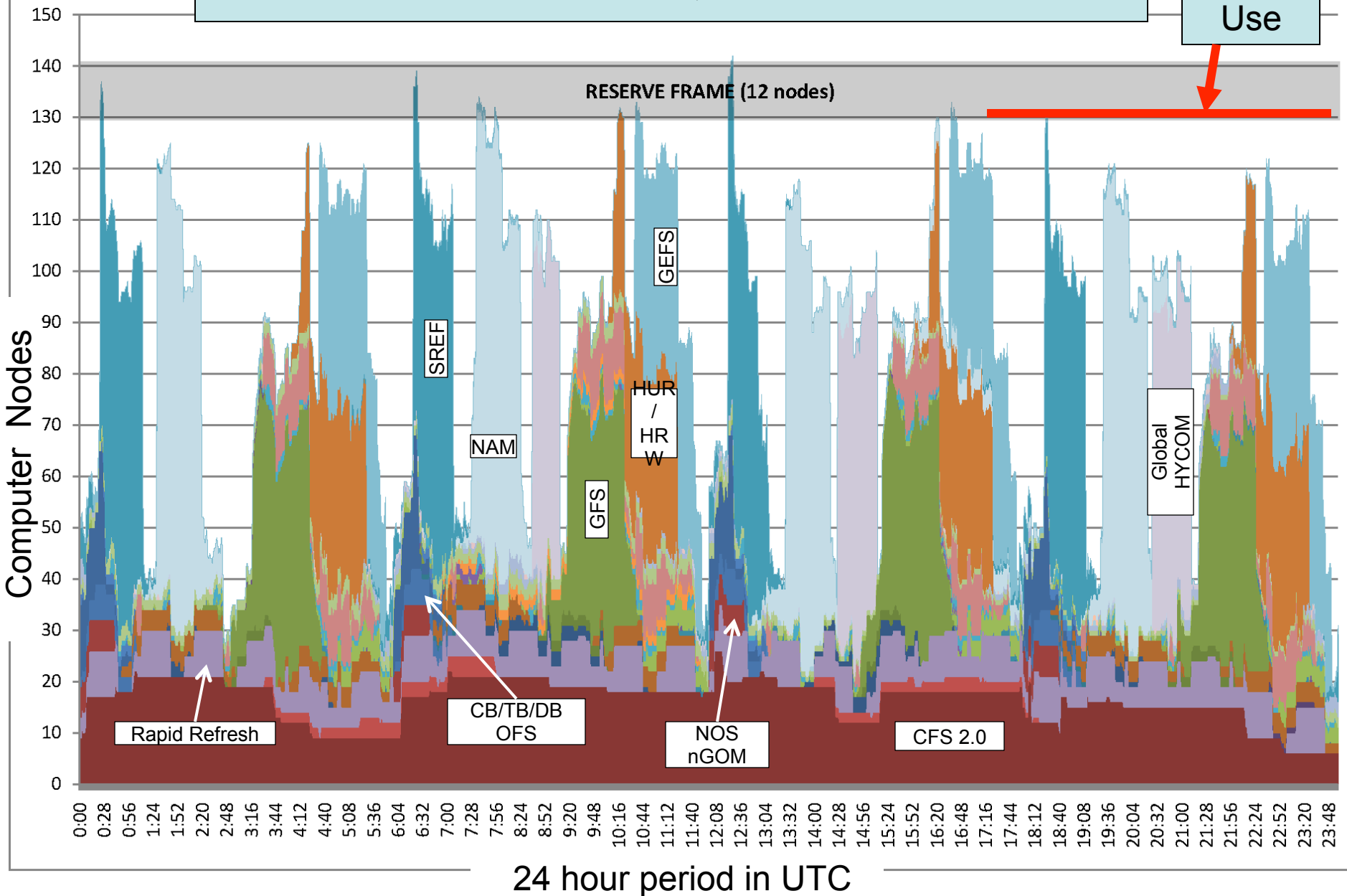
■ Data processing



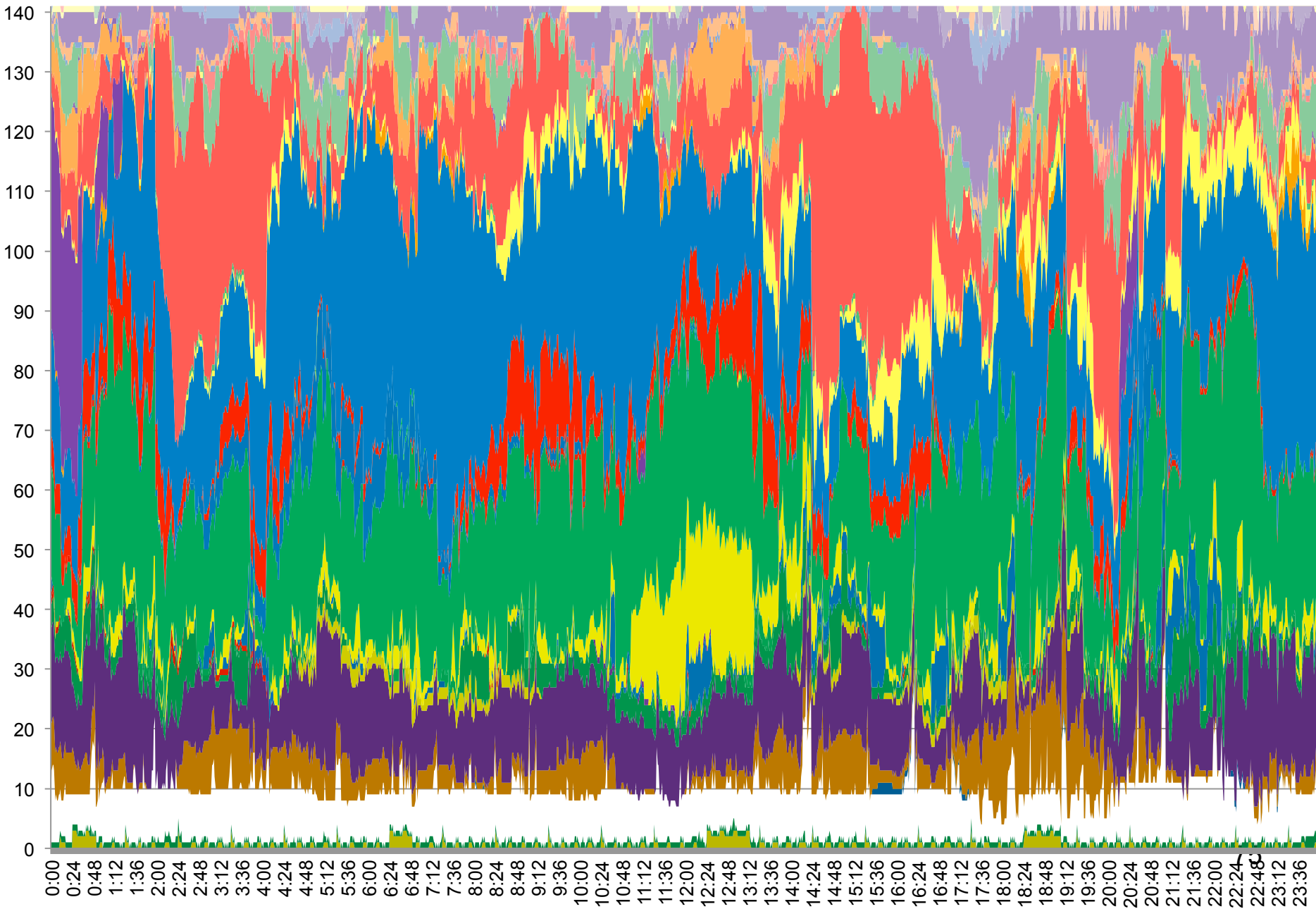
6 Hour Cycle: Four Times/Day

Operational NCEP Computer Use End of Q4FY11

Max
Node
Use



Development HWM 01/11/2011



Summary of Planned NEMS Capabilities (1)

- Components and capabilities of the NEMS infrastructure
 - Configuration control
 - Domain
 - Resolution (horizontal, vertical)
 - Standardized fixed field generation (NPS - topography, land use, etc)
 - Tracer definition
 - Nesting (static and moving, telescoping, 1-way, 2-way)
 - Concurrent ensemble execution (single executable, multiple members)
 - Data assimilation (3D-Var and advanced techniques)
 - Model dynamics and physics (including WRF schemes)
 - Atmosphere
 - Ocean
 - Land surface and hydrology
 - Air Quality, aerosols, and trace gases
 - Post-processor

Summary of Planned NEMS Capabilities (2)

- **Operational Models**
 - Global Forecast System
 - GFS
 - Global Ensemble (GEFS)
 - GFS
 - NMM-B
 - FIM
 - North American (NAM), nested apps (e.g. Fire Weather...)
 - NMM
 - Short-range Ensemble (SREF)
 - NMM
 - ARW
 - Physics diversity
 - High Resolution Window (HRW)
 - NMM
 - ARW
 - Rapid Refresh (RR) Ensemble
 - ARW Dynamics + GSD physics
 - NMM dynamics + NCEP physics
 - Aerosols
 - GOCART
 - Land Surface & Hydrology (LIS)
 - Noah & LIS
 - Hurricane (HUR)
 - NMM for hurricanes
 - HYCOM + Wavewatch
 - Ocean, waves and Seasonal Climate Forecast (CFS)
 - GFS for climate
 - MOM4
 - HYCOM-Wavewatch

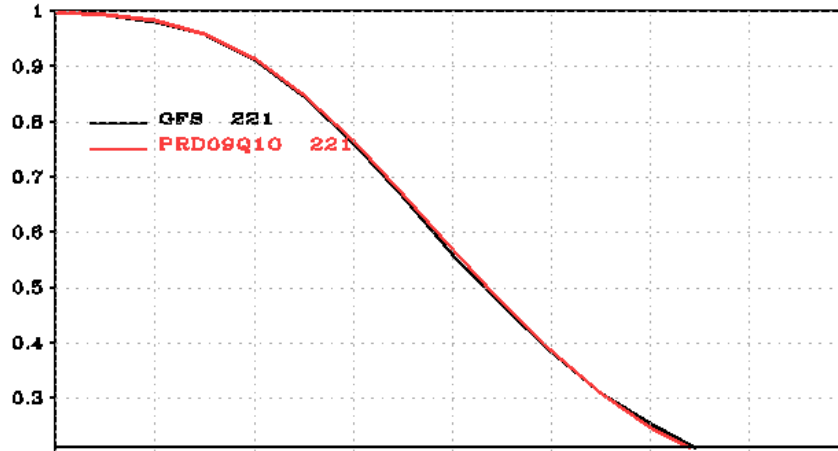
Planned NEMS Capabilities (cont)

- Modeling Research
 - Global and regional
 - Institutionally supported components
 - Atmosphere
 - GFS (NCEP)
 - NOGAPS (Navy)
 - FV (NASA, GFDL)
 - NMM (NCEP)
 - ARW (ESRL, NCAR, AFWA)
 - COAMPS (Navy)
 - FIM (ESRL)
 - FISL (NCEP)
 - Ocean
 - MOM4 (GFDL)
 - HYCOM (NCEP, Navy)
 - Waves
 - Wavewatch 3
 - Land surface and hydrology
 - Noah (NCEP) & LIS (GSFC)
 - VIC (Princeton, U. Wash)
 - MOSAIC (NASA)
 - Sacramento (OHD)
 - Smirnova LSM (ESRL)
 - Air Quality and trace gases
 - CMAQ (EPA, ARL)
 - WRF-CHEM
 - GOCART (NASA)
 - NAAPS (Navy)

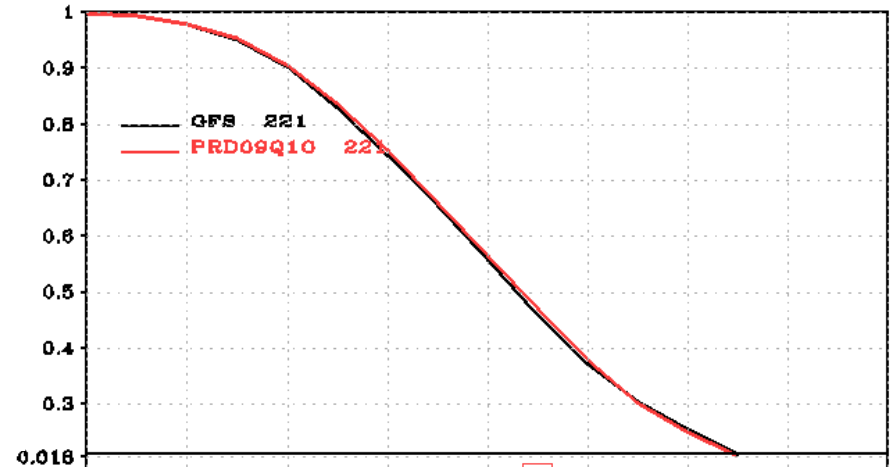
Under construction
Will include in future
Could include

500 hPa Anomaly Correlation

AC: HGT P500 Q2/NHX 00Z, 20080701-20090206

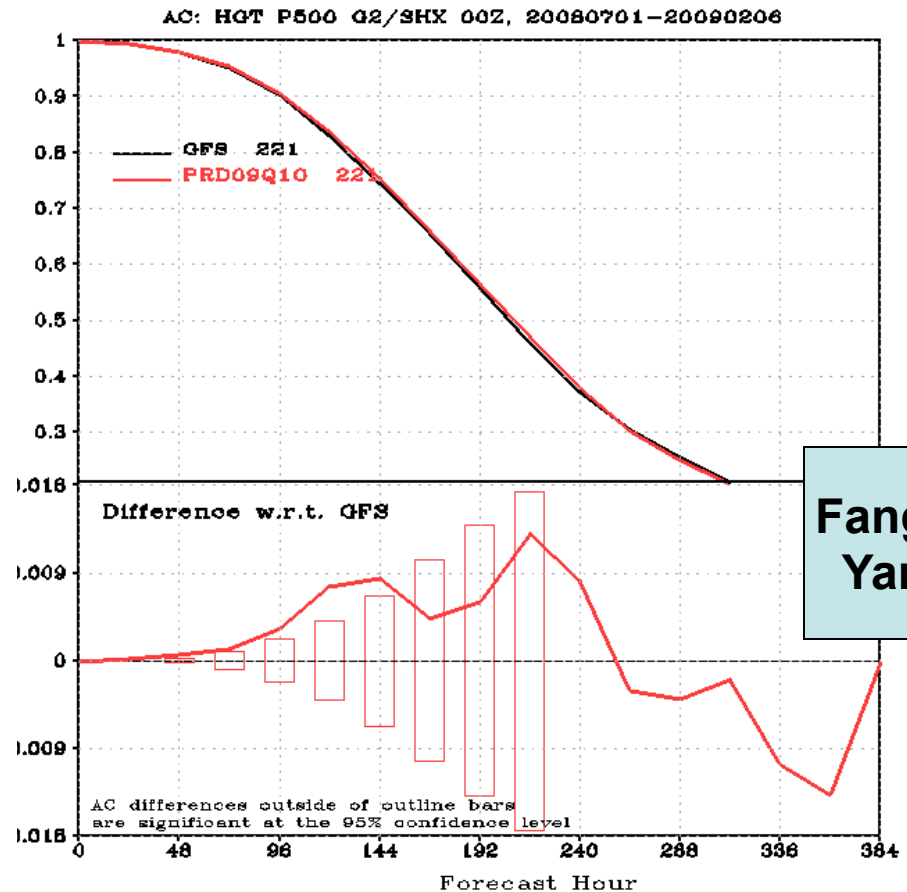
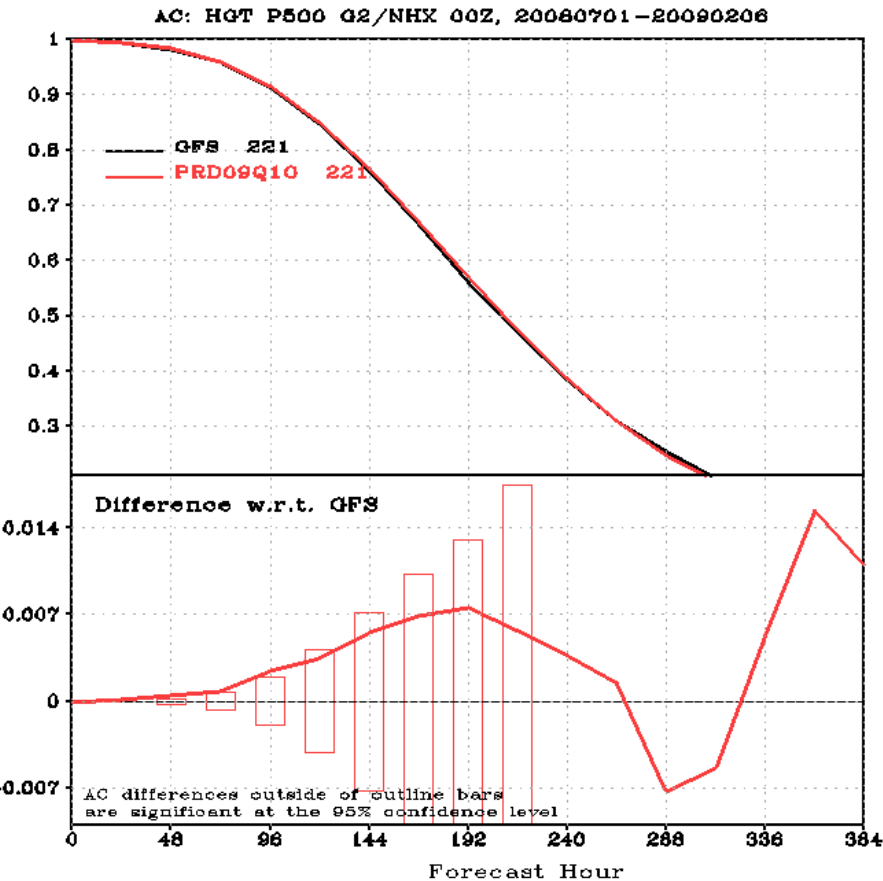


AC: HGT P500 Q2/SHX 00Z, 20080701-20090206



- “But these are just ‘width of the line’ improvements...”
- Why are these changes important to users?
- How can you justify \$M for new computing power based on these anticipated improvements?

500 hPa Anomaly Correlation

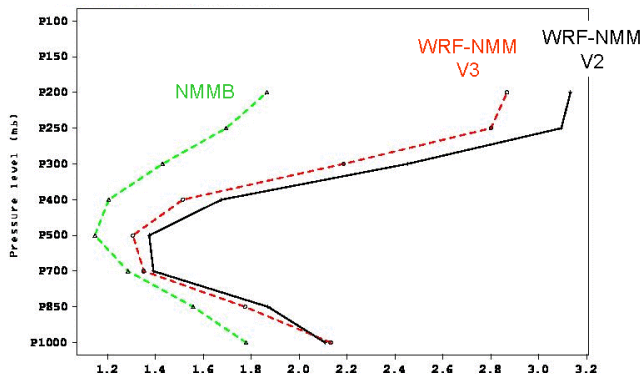


Fanglin Yang

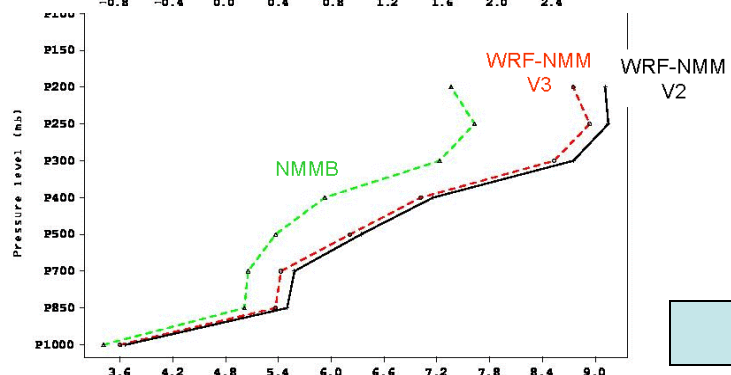
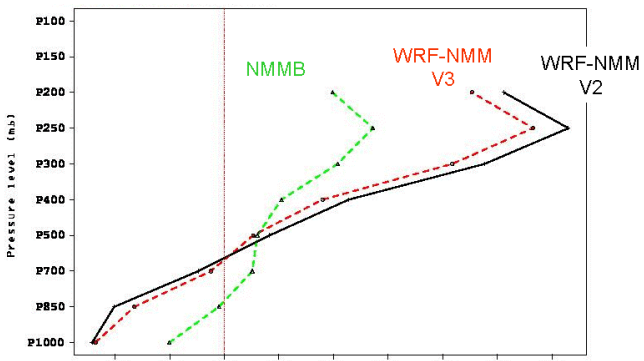
- **“They are statistically significant...”**
- Why are these changes important to users?
- How can you justify \$M for new computing power based on these anticipated improvements?

4 km NMM-B CONUS Nest – 36 h Fcst

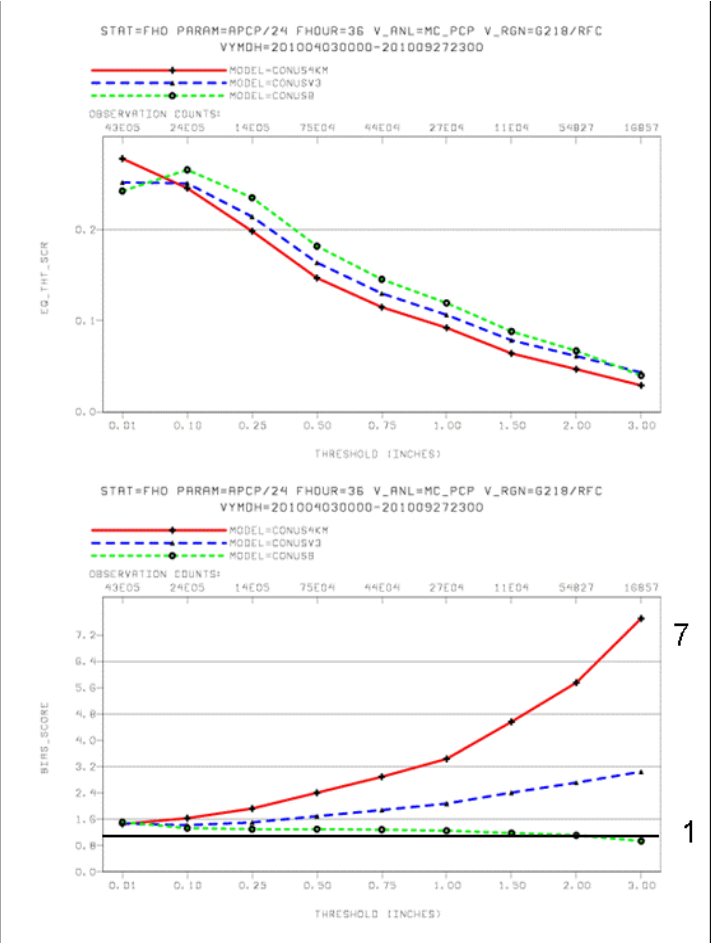
RMS Temperature Error



Temperature Bias



April 3 – Sept. 27 2010



WRF-NMM V2
WRF-NMM V3
NMMB

RMS Vector Wind Error